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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 92.
L. O. HOWARD, Entomologist and Chief of Bureau.

# WHITE FLIES INJURIOUS TO CITRUS IN FLORIDA.

BY

A. W. MORRILL, PH. D.,

AND

E. A. BACK, PH. D.

ISSUED JULY 12, 1911.

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FIG 1.—ORANGE COVERED WITH SOOTY MOLD.

FIG. 2.—LEAF OF ORANGE COATED WITH SOOTY MOLD.

A Hoen & Co Baltimore

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## *BUREAU OF ENTOMOLOGY.*

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Mabel Colcord, *librarian.*

# LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Entomology,
*Washington, D. C., March 2, 1911.*

Sir: I have the honor to transmit herewith, for publication as Bulletin 92 of the Bureau of Entomology, a manuscript prepared by Drs. A. W. Morrill and E. A. Back, dealing with the life history of the white flies injurious to citrus trees in Florida.

The investigation of the citrus white flies in Florida, under the general direction of the assistant chief of this bureau, Mr. C. L. Marlatt, was begun in 1906, and is now approaching completion. There has already been published a bulletin (No. 76) dealing fully with the general subject of fumigation with hydrocyanic-acid gas for the white fly. A circular (No. 111) has also been issued, giving brief directions for winter fumigation.

The present publication is a general account of the two species of white flies which are of special economic importance to the citrus grower in Florida. The publication includes the history of these insects in the United States, their distribution and food plants, and a very detailed study of the habits and life cycle of the two species. A great deal of painstaking and minute work has been done, and the information secured furnishes an accurate foundation for the developing of the best means of control.

Supplementing this publication, which deals largely with life history and habits, it is proposed to publish a bulletin on control by sprays, fungi, and other enemies, and to supplement or reissue in revised form the bulletin dealing with fumigation.

Respectfully,

L. O. Howard,
*Entomologist and Chief of Bureau.*

Hon. James Wilson,
*Secretary of Agriculture.*

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# WHITE FLIES INJURIOUS TO CITRUS IN FLORIDA.

## INTRODUCTION.

The present bulletin includes the principal results of studies of the two species of white flies most destructive to Citrus in the United States, commonly known as the citrus white fly (*Aleyrodes citri* R. & H.) and the cloudy-winged white fly (*Aleyrodes nubifera* Berger). With these pests successful control measures must be based on a complete understanding of the insects themselves. On this account the study of the insects, their life history, seasonal history, habits, food-plant relationships, and related topics has occupied an unusually important position in the white-fly investigations.

The authors have concluded that unless natural enemies capable of controlling the two white-fly pests are existent and are secured, control measures will require permanent expert supervision for the most satisfactory and economical results—not supervision of work in individual citrus groves, but supervision aimed principally to properly correlate individual efforts and to take full advantage of favoring local conditions. For supervision of this nature, a good foundation of extensive and reliable studies of the insects is necessary. While the portion of the white-fly investigations herein reported is comparatively extensive, it is necessarily not exhaustive and in the course of time certain features of this work can undoubtedly be continued with profit as an aid to the future improvement of control measures.

The white-fly investigations now in progress were begun in July, 1906, by the senior author, who was in field charge up to the time of his resignation from the bureau in August, 1909, The junior author's connection with these investigations dated from June, 1907. The life-history studies of the first two years have been largely superseded by the more extensive work of the third year. Practically all of the data presented under the subjects of the life history and habits and the seasonal history of each species are based on studies by the junior author and were written by him. The remainder of the bulletin was written by the senior author.

## SPECIES OF WHITE FLIES AFFECTING CITRUS.

Twelve species and one subspecies of the family Aleyrodidæ are known to breed upon citrus. The list of these insects, the authority for the original description, the recorded distribution, and the food-plant records are given in Table I:

TABLE I.—*Aleyrodidæ that breed upon citrus.*

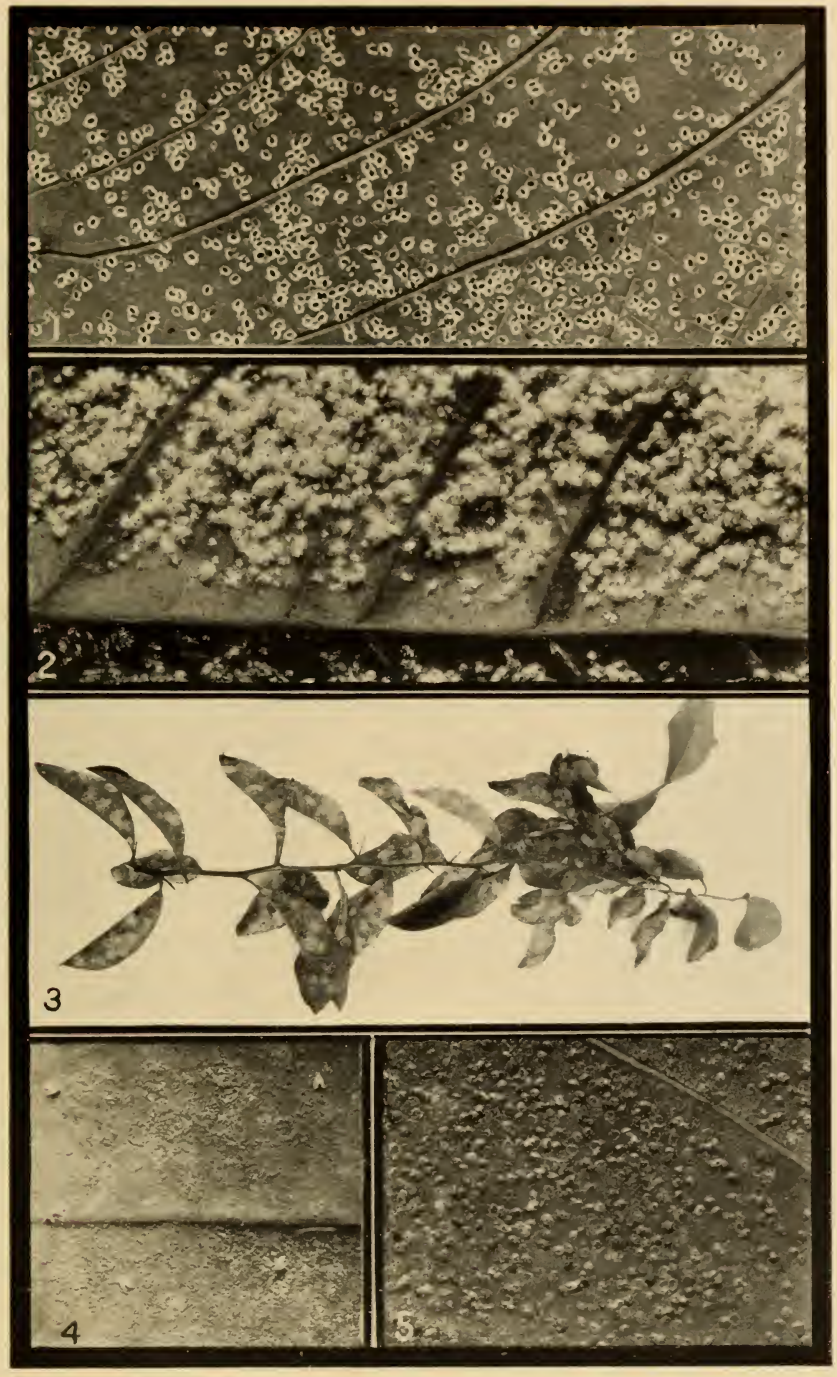
| Species. | Described by— | Occurrence. | Food plants other than citrus. |
|---|---|---|---|
| Aleyrodes citri (syn. aurantii).[1] | Riley and Howard. | North and South America, Asia, Japan. | See list, p. 29. |
| Aleyrodes floccosa | Maskell | Mexico, Jamaica | Guaiacum officinale. |
| Aleyrodes floridensis | Quaintance | United States (Florida) | Persea gratissima (alligator pear), Psidium guajava (guava). |
| Aleyrodes giffardi | Kotinsky | Hawaii | None recorded. |
| Aleyrodes howardi | Quaintance | Cuba, United States (Florida). | Do. |
| Aleyrodes marlatti | ....do | Japan | Do. |
| Aleyrodes mori | ....do | United States (Florida) | Do. |
| Aleyrodes mori arizonensis | Cockerell | United States (Arizona) | Do. |
| Aleyrodes nubifera | Berger | United States (Florida, Louisiana), Cuba. | Do. |
| Aleyrodes spinifera | Quaintance | Java | Rosa spp. |
| Aleyrodes struthanthi | Hempel | Brazil | Michelia flava, Loranthus (struthansus) flexicaulis. |
| Aleyrodes vitrinellus[2] | Cockerell | Mexico | None recorded. |
| Paraleyrodes perseæ | Quaintance | United States (Florida) | Do. |

[1] Mr. A. L. Quaintance, after careful comparison of material from Maskell's collection, evidently type material, with *A. citri*, concluded that Maskell's *aurantii* was the same as Riley and Howard's *citri*. Through the kindness of Mr. Quaintance the authors have had an opportunity to examine the material referred to and agree with him in considering *aurantii* a synonym of *citri*.

[2] There seems to be some doubt as to the identity of the food plant of this species, for in connection with the description the authority for it gives the following food plant record: "On the under side of leaves which appear to be those of orange."

Of the Aleyrodidæ referred to above, *A. citri*, *A. giffardi*, *A. howardi* (Pl. II, figs. 2, 4), and *A. nubifera* are known to be orange pests or capable of becoming orange pests. *A. floridensis*, *A. mori* (Pl. II, fig. 1), *A. mori arizonensis*, and *Paraleyrodes perseæ* (Pl. II, fig. 3) apparently are not likely to cause injury to citrus, while the remainder of those listed are doubtful in this respect.

*Paraleyrodes perseæ* is found in all sections of Florida and is frequently quite abundant, but in only one instance has it been known to cause blackening of the foliage of citrus trees. This was in the winter of 1906–7 and occurred in a pinery where in one section citrus nursery trees were being grown. In the course of two or three months after being first noticed the insects were reduced to the point of scarcity through parasitism by a new species of Encarsia, which Dr. L. O. Howard has described under the name of *Encarsia variegata*. Observations extending over three years indicate that this parasite will effectively control *P. perseæ* and that it is unlikely that this aleyrodid will ever cause noticeable injury under ordinary conditions. It is, however, possible that the appearance of a prolific hyperparasite of *Encarsia variegata* might seriously interfere with the present equilibrium in nature.




FLORIDA WHITE FLIES MISTAKEN FOR CITRUS AND CLOUDY-WINGED WHITE FLIES.

Fig. 1.—*Aleyrodes mori* on mulberry. Fig. 2.—Woolly white fly (*Aleyrodes howardi*) on orange. Fig. 3.—*Paraleyrodes persex* on orange. Fig. 4.—Woolly white fly (*Aleyrodes howardi*), showing eggs in circles and adults. Fig. 5.—*Aleyrodes* sp. on sea grape. (Original.)

The woolly white fly (*Aleyrodes howardi* Quaintance (Pl. II, figs. 2, 4)) was first discovered in this country at Tampa, Fla., by the junior author in November, 1909. The insect appears to be of recent introduction, since the infested area has been under observation at intervals during the past three and a half years by the several men connected with these investigations.[1]

Of the four species known to be destructive to citrus, *Aleyrodes citri* and *A. nubifera* are included in the investigations herein reported.

## THE CITRUS WHITE FLY.

(*Aleyrodes citri* R. & H.)

### HISTORICAL REVIEW.

#### Origin.

The origin of the citrus white fly is by circumstances quite definitely indicated to be Asiatic. The present known occurrence of it in Japan, China, and India will be referred to under the subject of distribution. The list of food plants, showing as it does the natural adaptations in this respect, indicates in itself that the fly is not native to either North or South America, but to Asia. Moreover, if the citrus white fly were a species native to the Gulf coast region of North America, or if it had been introduced before 1850, it would almost certainly have become a pest worthy of mention by Townend Glover in his reports on the orange insects of Florida published in the United States Agricultural reports for 1855 and 1858. According to these reports orange growing was very extensive in proportion to the population and very profitable in spite of the temporary check due to the freeze of 1835. The principal orange-growing district in Florida was, at the time of the reports of Glover, already mentioned, the northeastern section of the State, along the St. Johns River and at St. Augustine. Orange growing on a large scale gradually spread to the south and southwest, the center of production being correspondingly moved. To-day citrus fruits are generally grown in all the counties of the peninsula of Florida, yet, according to the authors' estimates, only about 40 per cent of the orange groves of the State are infested by *A. citri*.[2] These infestations in the different sections are almost without exception readily traceable to the ordinary sources of dissemination, with all the evidence strongly against the fly having been a native species infesting uncultivated food plants. The same may be said in regard to the occurrence of the citrus white fly in orange-growing regions in Mississippi, Alabama, Louisiana, and Texas.

[1] The Woolly White Fly, a New Enemy of the Florida Orange. Bulletin 64, Part VIII, Bureau of Entomology, U. S. Department of Agriculture, 1910.

[2] *A. nubifera* alone occurs in not more than 5 per cent of the groves. In 15 of the 40 per cent above mentioned both *A. citri* and *A. nubifera* occur.

### Early History in the United States.

Riley and Howard give the following account of the status of the citrus white fly previous to 1893:

For many years an important and interesting species of the type genus has been known to infest orange trees in Florida and in more northern greenhouses, and more recently the same form has appeared in injurious numbers in the orange groves of Louisiana. In the Florida Dispatch, new series, volume 11, November, 1885, this species received the name of *Aleyrodes citri* at the hands of Mr. Ashmead. The Florida Dispatch, however, is a local newspaper of no scientific pretensions, and the description accompanying the name was entirely insufficient to enable recognition aside from the food plant. We adopt the name in connection with a full description, not with a view of encouraging such mode of publication, which is not sanctioned by the canons of nomenclature formulated and generally accepted, but as a manuscript name, satisfactory in itself, the authority to be recognized for it being comparatively immaterial.

Our first acquaintance with the species was in June, 1878, when we found it occurring in profuse abundance on the leaves of the citrus trees in the orangery of this department. Some observations were made upon its life history during that summer, and all of its stages were observed. During the following years we observed it in Florida, and it was studied by two of our agents, Mr. H. G. Hubbard, at Crescent City, and the late Joseph Voyle, at Gainesville. The species was not treated in Mr. Hubbard's report on the insects affecting the orange, as we wished to give it a fuller consideration than could then have been given, and other duties prevented doing so in time. Moreover, at the time when Mr. Hubbard's report was prepared the insect had not become of especial economic importance.

Since that time many further notes have been made in Washington, and we have received the species from Pass Christian, Miss.; New Orleans, La.; Baton Rouge, La.; Raleigh, N. C.; and many Florida localities; and during the past year or two it has become so multiplied in parts of Louisiana and Florida as to deserve immediate attention.

The authors quoted above specifically recorded the occurrence of the white fly in Florida only at Gainesville (Alachua County), Crescent City (Putnam County),[1] and Manatee (Manatee County). Dr. H. J. Webber in 1897 (basing his statement on records in 1893 and 1894) referred to the occurrence of the white fly at the following additional points: Evinston (Alachua County), Ocala and Citra (Marion County), Ormond (Volusia County), Panasoffkee (Sumter County), Orlando (Orange County), Bartow (Polk County), and Fort Myers (Lee County). Prof. H. A. Gossard in 1903 mentioned only the following additional localities specifically: Tallahassee (Leon County), Lake City (Columbia County), Jacksonville (Duval County), and Candler (Marion County). In the same publication the following additional

[1] Examination of the specimens of white flies in the collection of the Bureau of Entomology, collected by Mr. H. G. Hubbard in 1895 and bearing the locality label "Crescent City," indicate that this record with little doubt refers to *Aleyrodes nubifera*. Circumstances known to the authors, but which need not be discussed here, show that with little doubt the citrus white fly was the species present at Crescent City before the freeze of the winter of 1894–5. The specimens collected by Mr. Hubbard probably came from the Hubbard grove at Haw Creek, several miles southeast of Crescent City.

counties were reported more or less infested without reference to definite localities: Baker, Jefferson, Leon, and Brevard.

Messrs. Riley and Howard and Dr. H. J. Webber advance no theories in regard to the original Florida infestations. Prof. Gossard, however, has the following to say in regard to the matter:

> The fly seems to have been first known throughout the region comprised in Volusia, Marion, Lake, Alachua, and Orange Counties, from which I have little or no doubt it was transferred to the Manatee country and to local centers along the northern borders of the State.

According to reliable information received from Mr. M. S. Moreman, of Switzerland, Fla.; Mr. A. M. Terwilliger, of Mims, Fla., and Mr. T. V. Moore, of Miami, Fla., the citrus white fly appeared in the northern part of St. Johns County at a date which indicates that this section was one of the first or possibly the first to be infested in the State of Florida. Mr. Terwilliger informs us that he first observed the white fly at Fruit Cove on the St. Johns River in 1879 in a grove of large seedling trees owned by Col. McGill. The McGill grove adjoined the grove of the Rev. T. W. Moore, whose son, Mr. T. V. Moore, corroborates Mr. Terwilliger on the point of the occurrence of the white fly in this section prior to 1880. According to Mr. Moreman the white fly was known in the vicinity of Switzerland on the St. Johns River in 1882, and was first discovered in his own grove in 1888. The species concerned is with little doubt the citrus white fly, *A. citri*, for the authors and Mr. W. W. Yothers have been unable to find specimens of any other species at Switzerland or St. Augustine, the two points visited in the northern part of St. Johns County, or at Green Cove Springs, located a few miles below Switzerland on the west side of the St. Johns River in Clay County. These early reports of the citrus white fly in this section of the State are supported by the fact that the earliest collected specimens of this species in the collection of the Bureau of Entomology bear the date 1888 and the locality label "St. Nicholas," a point located in Duval County about 15 miles north of Fruit Cove.

Interesting information concerning the early history of white-fly infestations in Florida has been obtained from Messrs. Borland and Kells, citrus growers at Buckingham, Lee County, Fla., formerly of Citra, Marion County. According to these gentlemen, the presence at or near Panasoffkee, in Sumter County, Fla., of a small white insect which caused blackening of the foliage of orange trees became known among orange growers around Citra, at that time in the heart of the orange-growing district of Florida, in 1881 or 1882. The grove of Bishop Young, of Panasoffkee, was one of the first reported infested. It is believed that Bishop Young, after traveling in Asia (Palestine?), brought back with him plants which he set out, and in a year or two thereafter blackening of the foliage of near-by

citrus trees in association with a new insect pest first became noticeable. The white fly affecting citrus trees at Panasoffkee was exterminated by the freeze of 1894–1895 and, so far as the authors can learn, has not reappeared. There seems to be at present no means of determining whether the report given above refers to the citrus white fly or to the cloudy-winged white fly.

Mr. A. J. Pettigrew, of Manatee, Fla., a reliable observer who has been in the citrus nursery and orange-growing business in Manatee County since 1884 and who has been familiar with the white fly since its first discovery in that country, has furnished the authors with a statement concerning the early history of the pest in that section of Florida. According to Mr. Pettigrew, Messrs. C. H. Foster and F. N. Horton each received from Washington, D. C., 6 tangerine trees in 1886 or 1887—as near as can be determined at this time, although possibly earlier by a year or two. A year or two after the trees were received and planted, the fly was noted by Mr. Pettigrew as abundant on a rough lemon near one of these tangerines, and the following year it was first noted as abundant in a seedling orange grove near by. At Mr. Pettigrew's suggestion specimens were sent to the Department of Agriculture at Washington and identified as a white fly. These specimens were probably sent to Washington in 1891, for a letter from Mr. Foster, dated January 8 of that year, was published in Insect Life[1] with the reply. The oldest specimens of the citrus white fly now in the collection of this bureau, which were collected in Manatee County, Fla., bear the date of March 5, 1891, with "Mantee" as the locality record. These were probably sent in by Mr. Foster in connection with later correspondence than that referred to above.

Concerning the history of the citrus white fly in Louisiana, Prof. H. A. Morgan in 1893 made the following statement:

> This pest, common from Baton Rouge to the Gulf, is known as the white fly. Orange growers claim that it has been recently introduced—that is, within the last ten years—and it is supposed to have come in upon plants brought to the New Orleans exposition in the year 1885. The present wide distribution of the white fly in the southeastern United States is due to the lack of restrictions, until very recently, against shipments of infested nursery stock and of privets and the Cape jessamine.

## Literature.

The citrus white fly was first given a valid scientific name and adequately described by Riley and Howard in an article published in Insect Life[2] in April, 1893. Following the account of the early history heretofore quoted, these authors describe the different stages of the insect in detail, give an account of the habits and life history, and give records with discussion of results obtained by a correspondent

[1] Insect Life, vol. 4, p. 274.

[2] Id., vol. 5, no. 4, pp. 219–226, 1893.

in Manatee County, Fla., who had undertaken some cooperative experiments in spraying.

During the same year (1893) Prof. H. A. Morgan, then entomologist of the Louisiana Agricultural Experiment Station, gave an account of the citrus white fly in Louisiana in a bulletin of that station.[1]

The Division of Vegetable Physiology and Pathology of the United States Department of Agriculture began investigations of citrus diseases in Florida in 1893. These included investigations of the "sooty mold" resulting from white-fly infestation, and the first report on the subject was published by Swingle and Webber in 1896[2] and a more extended report by Dr. H. J. Webber in 1897.[3] Conclusions from a series of spraying experiments are included in this publication and many important observations are recorded, particularly in connection with the two most useful fungous enemies of the white fly which were discovered by Dr. Webber in the course of his work.

Prof. H. A. Gossard, then entomologist of the Florida Agricultural Experiment Station, published, in 1903,[4] an account of the white fly situation up to that time, with his conclusions from observations extending over several years.

In a volume entitled "Citrus Fruits," published in 1904 by Prof. H. H. Hume, four chapters are devoted to citrus insect pests and methods of control, the white fly receiving due attention.

Since the present investigations by the Bureau of Entomology have been in progress, Dr. Berger, entomologist of the Florida Experiment Station, has published two bulletins[5] which present a summary of white-fly conditions with recommendations for control, particularly with reference to the use of fungous enemies. In the later published of the two mentioned, the specific distinctions are pointed out and illustrated, separating from the common *A. citri* the form which Dr. Berger has named *A. nubifera*.

Messrs. P. H. Rolfs and H. S. Fawcett, in a bulletin issued in July, 1908,[6] discuss in a general way the use of fungous parasites of the white fly in Florida and give recommendations for the introduction of the three most common species. The most important contribution to our knowledge of the fungous parasites of the citrus white fly is contained in a paper by Prof. H. S. Fawcett, published in 1909.[7]

---

[1] The Orange and Other Citrus Fruits. By W. C. Stubbs and H. A. Morgan. Spec. Bul. La. Agr. Exp. Sta., pp. 71–73, 1893.

[2] The Principal Diseases of Citrus Fruits in Florida. By W. T. Swingle and H. J. Webber. Bul. 8, Division of Vegetable Physiology and Pathology, pp. 25–28, 1896.

[3] The Sooty Mold of the Orange and its Treatment. Bul. 13, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1897.

[4] White Fly. Bul. 67, Fla. Agr. Exp. Sta., June, 1903.

[5] White Fly Conditions in 1906, the Use of Fungi. Bul. 88, Fla. Agr. Exp. Sta., January, 1907; White Fly Studies in 1908, Bul. 97, Fla. Agr. Exp. Sta., February, 1909.

[6] Bul. 94, Fla. Agr. Exp. Sta., July, 1908.

[7] Special Studies No. 1, University of State of Florida, 1909.

In Louisiana the demand for information concerning the citrus white fly has resulted in a publication on this subject by Mr. A. H. Rosenfeld in 1907.[1] The discovery of the white fly in California in the same year led to the publication, by Prof. C. W. Woodworth, of a circular of general information,[2] and of a second circular[3] dealing with the methods of eradication that were being employed in that State. A very complete account of the white-fly infestation in California was given by Mr. C. L. Marlatt, assistant entomologist of the Bureau of Entomology, before the Entomological Society of Washington.[4]

The foregoing paragraphs refer to the principal publications in which the citrus white fly is treated, exclusive of short papers in horticultural periodicals, press bulletins, experiment station reports, and transactions of the Florida State Horticultural Society. Numerous press bulletins have been issued by the Florida State Experiment Station dealing with several phases of white-fly control and written from time to time as the occasion demanded by Prof. Gossard, Dr. Sellards, Dr. Berger, and Prof. Fawcett.

Reviews of the white-fly situation for the year, with notes on new observations, have been included in their annual reports by each of the first three named, who have served successively as entomologist at the Florida Experiment Station. Many important papers and discussions on the white fly have been published in the Transactions of the State Horticultural Society, but for the most part these have been incorporated or the ground covered more fully in the regular bulletins referred to.

Taken as a whole, the literature on the citrus white fly is quite extensive, giving a fairly good idea of the status of the white fly and progress in methods of control from year to year since the publication of the paper by Riley and Howard referred to in the opening paragraph.

The description of the different stages and the account of the life history and habits of the citrus white fly by Riley and Howard have been followed quite closely by subsequent writers, few additional records having been made up to the beginning of the present investigations. Records of food plants, miscellaneous life-history records, general results of field experiments, and conclusions from general observations on the efficiency of spraying, fumigating, and natural control by fungous diseases have been published by Messrs. H. J. Webber, H. A. Gossard, E. H. Sellards, E. W. Berger, and H. S. Fawcett. Comparatively little real data has been published so far in

[1] Circular 18, State Crop Pest Commission of Louisiana, 1907.

[2] Circular 30, California Agricultural Experiment Station, 1907.

[3] Circular 32, California Agricultural Experiment Station, 1907.

[4] Proceedings of the Entomological Society of Washington, vol. 9, pp. 121–123, 1908.

connection with experimental work with the white fly. A review of all the literature to date shows that data have been published on the effect of kerosene emulsion on white-fly eggs, by Riley and Howard; on the subject of effects of cold upon white-fly larvæ and pupæ, by Prof. Gossard; on the percentage of trees infected by the spore-spraying method of introducing the fungous parasites, and on the amount of honeydew secreted by the larvæ of the insect, by Dr. E. W. Berger; upon subjects related to fumigation,[1] by the senior author of the present bulletin; and on laboratory experiments with the fungous parasites, by Prof. H. S. Fawcett. Aside from the above, practically no data have been heretofore published.

## INJURY.

### Nature of Injury.

The direct injury by the citrus white fly may be included under two main heads: (1) Injury by removal of sap from foliage, and (2) injury from fungous growth known as sooty mold (Meliola), which develops upon foliage and fruit on the excretions of the insects.

The direct injury is principally included as loss in value of trees, extra expenses of maintenance, and losses from scale insects and diseases, which more seriously affect white-fly infested trees.

### LOSS OF SAP.

The amount of sap extracted by the insects is not generally considered an item of great importance compared with the injury from sooty mold. While the extraction of sap by itself probably would not cause sufficient injury to make the white fly rank as an important citrus pest, it is doubtless of considerable importance when combined with the lowered assimilative powers of the foliage due to the sooty mold. As mentioned more in detail under the subject of feeding habits, it has been estimated that the loss of sap per day amounts to about one-half of a pound for 1,000,000 larvæ and pupæ.

### SOOTY MOLD.

Sooty mold is the principal evidence of white-fly injury, and is the most important element of damage, affecting both the foliage and fruit. (See Pl. I, frontispiece.) No special attention has been given by the authors to its botanical aspects, but the following notes concerning it are taken mainly from Dr. H. J. Webber's report on this subject:[2]

[1] Fumigation for the Citrus White Fly as adapted to Florida Conditions. Bulletin 76, Bureau of Entomology, U. S. Department of Agriculture, Oct. 31, 1908.

[2] Bulletin 13, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, pp. 5–11, 1897.

The sooty-mold fungus is a species of the genus Meliola [1] of the order Pyrenomycetes. Dr. Webber states that in Florida and Louisiana it is quite generally known as smut or black smut, but as the fungus concerned is not a smut fungus these terms are erroneous, and their use should be discontinued. When abundant on leaves and fruit of citrus, this fungus forms a dark-brown or black membranous coating composed of densely interwoven branched mycelial filaments. At first this coating covers only limited spots or is not thick enough to form a distinct membrane, but later, if the honeydew-secreting insects are abundant, the coating becomes thick enough to be entirely removed from the leaf and torn like paper. (Pl. III, figs. 1, 2.)

Frequently the fungus membrane becomes detached at some point and is caught by the wind and large fragments torn off. These fungus fragments are found scattered about in badly infested groves in the fall, being especially noticeable during the winter after a high wind or after the trees have been sprayed.

Dr. Webber recognized several forms of reproductive agents, which are easily distributed by various means, but principally by winds. The fungus is entirely saprophytic in so far as known, deriving its nourishment from the honeydew secreted by certain insects. As such honeydew falls mostly on the upper surface of the leaves and on the upper half or stem end of the fruit, the sooty mold develops most densely in these places, but it is usually present to a greater or less extent on the lower surface of the leaves, sometimes developing in tufts on drops of honeydew which diseased insects fail to expel in a normal manner. Sooty mold also develops on the twigs and in some cases on the sides of buildings when heavily infested trees are growing near by.

*Seasonal history of sooty mold.*—The sooty mold resulting from the attacks of the citrus white fly is most abundant late in the season. Very little sooty mold develops during the winter months, while the films of blackish mycelium gradually become removed from the leaves by winds and rains and much is knocked off in picking the fruit, in spraying, pruning, fumigating, etc. The thicker the coating of sooty mold, the more readily and thoroughly it is removed. By the time of the appearance of the new spring growth the greater part of the sooty mold on the old leaves has disappeared and from this time to the 1st of May there is very little, if any, evidence of a new growth of this fungus. Slight blackening of spring growth has been noted as far north as Island Grove in Alachua County, Fla., as early as May 20, the average number of live larvæ and pupæ per leaf being estimated as about 50, not including old leaves which were practically uninfested. By June 20, leaves from McIntosh, in the same county,

[1] Generally referred to *M. camelliæ* (Catt.) Sacc., but perhaps including more than one species.

SOOTY MOLD.

Fig. 1.—Sooty mold on orange leaf following white-fly attack; broken and falling from leaf.
Fig. 2.—Sooty mold on cinnamon tree following attacks by cinnamon scale. (Original.)

with an average of about 11 live larvæ and pupa cases[1] per leaf, were slightly blackened. In general, heavy coats of sooty mold on leaves are common in Florida by the 1st of June in groves heavily infested by the citrus white fly.

*Effect of sooty mold on leaf functions.*—Dr. Webber has discussed the effect of sooty mold on leaf functions in the report already referred to, and as there is nothing to add at this time, the following paragraph (pp. 10–11) is quoted:

> When it is remembered that various investigations have shown that the process of phytosyntax[2] is almost entirely checked in a plant placed in the back part of a living room, opposite a window, where the light is fairly bright, but diffused, it can readily be judged that the effect of the dark, compact mycelial membrane of the sooty mold covering the leaves would be to almost wholly check the process of phytosyntax in the orange tree. Quite bright or direct sunlight is necessary for the best results. The injurious effects of sooty mold on the phytosyntax was clearly demonstrated by Busgen. He removed the fungus membrane from a small portion of a leaf and exposed the leaf to the sun. In the evening, after a sunny day, the leaf was plucked and the chlorophyll extracted with alcohol. After this leaf was treated with iodine, the parts from which the membrane had been removed in every case stained a dense blue, indicating the formation of an abundance of starch, while the surrounding portions of the leaf, which were protected from the sun by the fungus membrane, remained entirely uncolored, showing that no starch was formed. The stomata, or breathing pores, are also to some extent closed by the sooty mold, and in this way the passage of gas is more or less hindered. In the orange leaf, however, the stomata are confined to the lower surface, where generally there is but little sooty mold. In plants where the stomata are on the upper surface of the leaf also, the damage resulting from the obstruction of the passage of gases would probably be considerably greater.

## Extent of Injury.

In the following discussion the statements concerning injury and the estimates of the extent of this injury by the citrus white fly refer to groves in which the fly has become well established and in which no remedial measures have been practiced.

### Injury to fruit.

Unless otherwise stated, oranges and tangerines are referred to. These constitute more than 88 per cent of the citrus fruit crop of Florida. The total injury to grapefruit by the citrus white fly is rarely over 15 per cent and is frequently inappreciable.

*Ripening retarded.*—Ripening of fruit on heavily infested citrus trees is greatly retarded, and in case of the formation of a very heavy coating of sooty mold on the upper half of the orange the rind underneath it may remain green indefinitely while the lower half of the fruit is

[1] Some of the first generation had matured, but are properly included with the insects responsible for the sooty mold present.

[2] "Phytosyntax" refers to the process of the formation of complex carbon compounds out of simple ones under the influence of light; "photosynthesis" is a more common term for this process of assimilation.

well colored. The retardation of ripening, delaying as it does in some cases the time when the fruit is marketable and materially increasing the percentage of culls, causes injury which is very conservatively estimated to range from 2 to 5 per cent of the value of the crop. The injury to grapefruit in retardation of ripening by the citrus white fly is much less, varying from none at all to 2 or 3 per cent.

*Number and size.*—The greatest injury by the white fly is in the reduction of the salable crop of fruit. Dr. Webber on this point makes the following statement:[1]

> The effect of the sooty mold on the orange is very noticeable, the growth being usually greatly retarded and the blooming and fruiting light. In serious cases growth is frequently entirely checked, and blooming and fruiting wholly suppressed until relief is obtained.

Prof. Gossard has estimated [2] that during a six-year period the reduction in yield due to the citrus white fly is from 25 to 40 per cent.

Replies to a circular letter of inquiry addressed to orange growers and the observation of the authors in Florida indicate that the reduction in yield due to the citrus white fly amounts to 50 per cent, on the average, when no artificial methods of control are practiced.

From information received from many growers and from personal observation, the authors would estimate that with continued good care and with the additional fertilizer usually given infested trees the reduction in yield in different groves in a series of years amounts to an average between 20 and 50 per cent.

The decrease in yield due to white-fly infestation ordinarily consists of a decrease in the actual number of fruit produced and also in the packing size. From information obtained it seems a conservative estimate to consider that oranges and tangerines are reduced either one or two packing sizes as a result of white-fly attack. For each packing size, the number of reduced fruit remaining the same, the reduction in the crop would average about 12.5 per cent.

*Expense of cleaning.*—Fruit noticeably affected with sooty mold requires cleaning before marketing. One of the most economical machines for washing fruit used in Florida is a California washer used by Mr. F. D. Waite, of Palmetto, and Mr. F. L. Wills, of Sutherland. The cost of washing with these machines ranges from 1.4 to 2.5 cents per box. The cost of cleaning with the simplest machines is about 5 cents per box. Mr. E. H. Walker, of Orlando, Fla., estimates the cost of hand cleaning oranges at 10 cents per box as a minimum and 7 cents a box for cleaning grapefruit. In consideration of the foregoing it is estimated that the range in cost of cleaning the sooty mold from fruit to be from 1 to 10 per cent of the value of the crop.

*Shipping and keeping quality.*—The sooty mold produced by the white fly and other citrus pests does not, so far as known, affect the

[1] Loc. cit., p. 9. [2] Bul. 67, Fla. Agr. Exp. Sta., p. 617.

shipping quality of the fruit directly, but the processes of cleaning have been proved to be of considerable importance in this respect. The subject of the deterioration in shipping quality of citrus fruits has been thoroughly investigated in California by agents of the Bureau of Plant Industry under the direction of Mr. G. H. Powell.[1] Their report shows in a conclusive manner that the amount of decay in shipment is very materially increased by brushing or washing the fruit to remove the sooty mold. Table II, arranged from data published in the report referred to, shows the effect of dry brushing and washing fruit on the percentage of decay.

TABLE II.—*Effect, on decay, of cleaning sooty mold from fruit.*

| Record No. | Unbrushed fruit apparently sound. | Dry brushed fruit apparently sound. | Washed fruit apparently sound. |
|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* |
| 1..... | 2.7 | 6.6 | 17.8 |
| 2..... | 1.9 | 4.2 | 10.0 |
| 3..... | ..... | 1.8 | 2.6 |

It will be observed that dry brushing increased the amount of decay to about two and one-half times the decay in the unbrushed in record No. 1, and to about two and one-fifth times in record No. 2. Washing increased the amount of decay to about six and two-thirds times in record No. 1, and to about five and one-fifth times in record No. 2.

The injury from cleaning the fruit is due to the increased opportunities for infection with spores of the blue mold and to mechanical injuries in the process of cleaning. The chances of decay are still further increased whenever the fruit is not thoroughly dried before packing. Washing in constantly running water or by running the fruits through brushes with water constantly sprayed over them is considered much less objectionable than the ordinary systems.

*Flavor.*—The attack of the white fly is generally supposed to affect the quality of the fruit in a marked degree. Dr. Webber and Prof. Gossard describe the flavor as insipid as a result of heavy infestations. The latter presents the results of chemical analyses of samples of the fruit of tangerine trees in two adjoining groves. In one grove the white fly was completely controlled by spraying; in the other the fly was unchecked. The analyses showed that there was, in the samples from the latter grove, 15 per cent less reducing sugar, 15 per cent less sugar dextrose, and 5 per cent less citric acid. While oranges and tangerines are frequently much affected in flavor, thoroughly blackened groves in many cases produce as well flavored fruit as can

[1] Bulletin 123, Bureau of Plant Industry, U. S. Department of Agriculture.

be found in the market. When trees are supplied with as much fertilizer as they can use to advantage the white fly does not ordinarily affect the flavor of the fruit to such a noticeable extent as is commonly believed. It is suspected that a well-grounded prejudice against the white fly rather than a discriminating taste is responsible for a large part of the supposed effect on the flavor of the fruit in infested groves.

*Increased injury from scale insects and from plant diseases.*—The number of culls is in some cases very much increased by diseases and insect pests which thrive after the trees have been weakened by the white fly. There are no data available showing the usual increase in percentage of fruit injured by scales and by diseases of the trees as a result of white-fly infestation, but this is a consequence observed by many citrus growers and is properly considered a factor of white-fly injury. As such it is conservatively estimated to vary from 1 to 5 per cent in groves thoroughly infested, although an instance of a valuable crop being completely ruined by secondary scale attack has come under the authors' observation.

*Market value.*—Imperfections in fruit rind due to diseases and insect pests as followers of the white fly and to failure of fruit rind to color up normally, in addition to the direct effect on the size of the marketable crop as heretofore discussed, usually lower the average grade even after the fruit is cleaned by the most approved methods. A few growers claim that after being cleaned their oranges and tangerines bring as good prices as any, and leaving out of consideration instances where it is claimed that most or all of the fruit is rendered absolutely unsalable under any conditions, we may conservatively estimate the depreciation in market value to range from none at all to 10 per cent.

Sooty-mold-blackened oranges shipped without cleaning have a market value ordinarily from 25 to 50 cents less per box than the same fruit would have cleaned.[1] Certain Florida brands of oranges well advertised, carefully graded, and packed, would fail to bring within a dollar a box of their average value if they appeared on the market blackened by sooty mold.

*Losses to growers estimated on basis of prices paid by orange buyers.*—The authors are indebted to Mr. E. H. Walker, of Orlando, for the information that during the season of 1907–8 orange buyers in Florida paid from $0.75 to $1.45 for oranges free from white-fly effects, and from $0.50 to $1 per box for fruit blackened by white fly; during the season of 1908–9 the price paid for clean fruit varied from $0.60 to $1 per box, and from $0.50 to $0.75 for fruit blackened by sooty mold. The loss to the growers is not entirely represented by these

[1] Statement based on information from Mr. E. H. Walker, Orlando, Fla.

figures, since, according to Mr. Walker, the best prices were not paid for sooty-mold-blackened fruit until late in the season after the clean fruit had nearly all been shipped or disposed of. Clean fruit at this time would have been proportionally more profitable.

### INJURY TO TREES.

*Weakening of vitality.*—It is doubtful if the white fly is ever the direct cause of the killing of trees, limbs, or twigs in well-fertilized groves. It does, however, seriously stunt the growth of all heavily infested trees, and may temporarily entirely check the growth of young trees. Its greatest effect on the vitality of the tree is an indirect one. Infestation by the white fly appears to weaken the resistance of orange and tangerine trees to foot rot, die back, melanose, wither tip, and drought, and favors the multiplication of the purple and long scales which are second to the citrus white fly as citrus pests in the Gulf coast regions.

*Depreciation in value.*—The selling values of citrus groves are greatly reduced by white-fly infestation, and citrus nurseries have their territory for sales much restricted and values reduced. Concerning the reduction in value of groves of bearing trees one of the most experienced dealers in orange groves in the State estimates that it is in general about one-third. For years California has been closed to Florida nurserymen as a field for the sale of citrus nursery trees, and a similar quarantine regulation has recently gone into effect in Arizona. In Florida and in citrus-growing sections of other Gulf coast States a guaranty of freedom from white fly is generally required, especially when the purchaser contemplates planting a more or less isolated grove.

### SUMMARY OF LOSSES.

The estimates in the foregoing pages refer to ordinary losses where the white fly is unchecked by natural enemies or by artificial methods of control and not to exceptional or occasional losses. These estimates, as applying to the fruit, are summarized in Table III.

TABLE III.—*Estimates of losses to orange crops by white fly in uncontrolled condition.*

| | Maximum. | Minimum. | Mean. |
|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* |
| Ripening retarded | 5 | 2 | 3½ |
| Number and size of fruits | 50 | 20 | 35 |
| Cost of cleaning | 10 | 1 | 5½ |
| Deterioration in shipping quality | 6 | 2 | 4 |
| Indirect injury: Increased scale and disease effects on fruit | 5 | 1 | 3 |
| Loss in market value | 10 | 0 | 5 |
| Total | 86 | 26 | 56 |

The mean of the total percentage of estimated loss is considered by the authors to represent about the normal loss which the citrus white fly is capable of causing in orange groves. It is estimated that the condition is reduced to about 45 per cent loss in the average infested grove as a result of net profits from spraying with contact insecticides and of the natural efficiency of fungous diseases.

From extensive records obtained in the course of their investigations the writers estimate that the citrus white fly infests at present 45 per cent of the citrus groves in Florida. Of this, 5 per cent is a sufficient allowance to represent the groves so recently infested that normal abundance of the pest has not been reached. An injury of 45 per cent in 40 per cent of the groves is equal to about 18 per cent of the entire value of the crop as it presumably would have been if the white fly were not present.

The latest Florida citrus crop concerning which statistics are available is that of 1907–8.[1] The orange crop for that season is valued at $3,835,000. With an estimated total loss of about 15 per cent this represents 85 per cent of the value of the crop if not affected by the white fly. Accordingly, the estimated loss in Florida is calculated to have been about $680,000 for oranges and similarly on the basis of 10 per cent loss to grapefruit on a valuation of $469,700, the percentage of infested groves the same as in the case of the orange groves, a loss of $16,700 is estimated, making the total loss in valuation of fruit about $696,700 for the crop of 1907–8. The crop of 1908–9 was doubtless affected to the extent of $750,000 by the citrus white fly.

At present the spread of the fly into uninfested groves is undoubtedly faster than at the rate of 5 per cent new infestations per year. Even on this basis, however, the annual increase in depreciation in the value of Florida citrus groves due to white-fly infestation is more than $200,000 per year.[2] In addition, the citrus nursery business in Florida is affected to an extent hard to estimate, but which would be only nominally represented by $50,000 per year.

Figures are not available which would allow approximate estimates to be made of the damage by the citrus white fly in the Gulf coast citrus-growing sections outside of Florida, but the widespread occurrence of the white fly in those States indicates that the losses are heavy.

### INCREASED COST OF MAINTENANCE.

The items of expense of maintenance principally affected by the white fly are fertilization, spraying, and fumigation. In Florida

[1] Tenth Biennial Report of the Commissioner of Agriculture of the State of Florida.

[2] This is not shown by actual depreciation, for the number of groves coming into bearing for the first time each year more than covers the loss.

ordinarily the expense of the fertilizer necessary to maintain orange trees in good productive condition varies from 10 to 20 cents per box of fruit produced. The wide range given is largely due to differences in soil conditions. Mr. E. O. Painter, in response to an inquiry on the subject, writes that citrus trees infested with white fly in his opinion require at least 15 per cent increase in fertilizer for best results under the circumstances. On the basis of cost of fertilizer amounting to 10 to 20 cents per box and an increase of 15 per cent due to white fly infestation, the extra expense which may be charged as white fly injury amounts to 1.5 to 3 cents per box.

*Cost of control measures properly chargeable to increased cost of maintenance.*—Estimates based on the experience of the writers in fumigating and in spraying for the white fly give the range in expense of the former method of control as 5.5 to 14 cents per box of oranges produced, and of the latter method 12.5 to 20 cents per box. These estimates refer to thorough control, with the result that production is entirely unaffected by the white fly. The minimum estimate on the expense of fumigation refers to groves so located that the migrations of adults from outside groves does not make treatment necessary more than once in two years. The maximum estimate refers to conditions where treatment every year is required to prevent loss. Increase in production, due to destruction of scale-insect pests, is not taken into consideration. In the estimates of expense of control by spraying the minimum estimate refers to cases where three applications of insecticide per year have resulted in satisfactory control. This result can be attained only after the insect has been brought into complete subjection, such as referred to in the introductory paragraph of the subject of artificial control. Insecticides costing more than 1½ cents per gallon when mixed ready for application have not been taken into consideration.

## DISTRIBUTION.

As has been shown in the historical review, the citrus white-fly at present is generally distributed in North America. In the northern part of the United States it occurs in greenhouses, and in the southern part, and in limited districts in California, it occurs on citrus, China trees, privet, cape jessamines, and other food plants. In the present publication we are concerned only with the distribution of the species in the citrus fruit-growing regions of the United States.

### In the United States.

According to the statistics of the Florida commissioner of agriculture, in 1905 there were 17 counties in the State reporting more than 5,000 bearing citrus fruit trees. In all but two of these, Dade and St. Lucie, the citrus white fly (*Aleyrodes citri*) occurs to a greater

or less extent. (See fig. 1.) The 17 counties referred to, arranged in order of the number of bearing citrus trees, is as follows: Orange, Lake, Volusia, Polk, Putnam, Brevard, Hillsboro, De Soto, Lee, Manatee, Dade, Marion, St. Lucie, Osceola, Sumter, St. John, and Alachua. Palm Beach as well as Dade and Monroe Counties are infested with the cloudy-winged white fly, as hereafter noted, but so far as known the citrus white fly does not occur there. In order of the percentage of groves infested the foregoing counties which are known to be infested would be arranged about in the following order, so far as our observations and records show: Marion, Alachua, St. John, Manatee, Orange, Lee, Volusia, Polk, Putnam, Lake, Hillsboro, Sumter, De Soto, Osceola, and Brevard. If the groves infested by the cloudy-winged white-fly only were also taken into consideration, Hillsboro and Lake Counties would be transposed in the list, as would Osceola and Brevard, but aside from this there would be no change. The arrangement is only approximate, being based on observations made by the various men connected with the white-fly investigations upon information and samples of infested leaves received from correspondents and upon nearly 250 replies received in response to circular letters sent out in the spring of 1907.

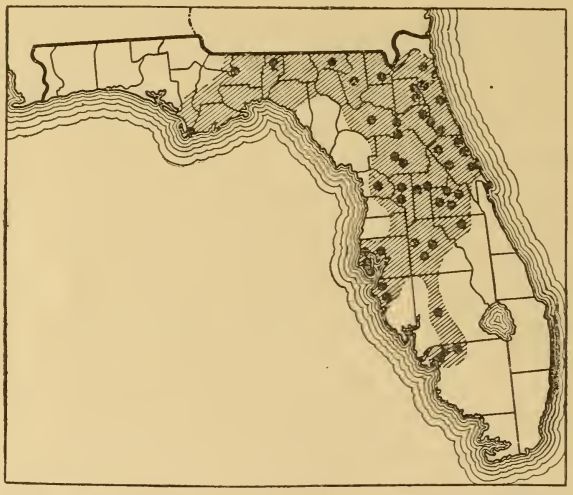


FIG. 1.—Map showing distribution of the citrus white fly (*Aleyrodes citri*) in Florida. (Original.)

At the present time the writers estimate that throughout the State of Florida about 40 per cent of the citrus groves are infested by the citrus white fly, and that an additional 5 (or 10) per cent are infested by the cloudy-winged white fly alone.

The citrus white fly occurs in nearly all the larger towns in northern Florida, infesting the various food plants which are grown as ornamentals as well as the citrus fruit trees which are grown to a limited extent. The insect is of common occurrence, principally on China trees, cape jessamines, and on privet and hedges of *Citrus trifoliata* in South Carolina and in southern Georgia, Alabama, Mississippi, Louisiana, and Texas. In the last two States citrus fruits are being grown quite extensively, and a large percentage of the citrus-growing localities are infested.

Aside from the Gulf coast States, citrus fruits in the United States are grown only in California and Arizona. The citrus white fly does not occur in Arizona. In California the pest was first discovered in May, 1907. Mr. C. L. Marlatt has given the following account of the distribution of the white fly in that State in 1907:[1]

> Marysville is situated a few miles north of Sacramento, and the first infestation seemed limited to this town, but toward the end of the summer the white fly was discovered well established at Oroville, in Butte County, some 26 miles to the north of Marysville. The Marysville infestation was confined to the town and to yard trees or small garden orchards. Oroville lies in a considerable orange district, and the white fly had been carried from the town into several of the adjacent orchards and had become rather widely scattered. Shortly after the discovery of the fly at Marysville it was found also to have established itself locally near Bakersfield,[2] in the southern end of the San Joaquin Valley, and separated only by a mountain range from the citrus districts of southern California.

### In Foreign Countries.

For years the citrus white fly has been supposed to be an introduced species, and much interest has been attached to its occurrence elsewhere than in North America. Prof. H. A. Gossard in 1903 stated that Mr. Alexander Craw, of the California State commission of horticulture, had received this species on plants from Chile, where it was reported to be a great pest. Mr. G. W. Kirkaldy, in his catalogue of the Aleyrodidæ, in 1907, gives "Mexico, Brazil, and Chile (?)" as the known habitats of the citrus white fly outside of the United States. The writers are informed by Prof. A. L. Quaintance that he was told in person by the late Prof. Rivera, of Santiago, Chile, that the citrus white fly was abundant in that country. Prof. Carlos Camacho, chief vegetable pathologist at Santiago, Chile, is also, according to Prof. Quaintance, authority for the statement that it occurs there.

The Bureau of Entomology received, in 1906, specimens of an aleyrodid on orange leaves from China which Prof. Quaintance determined as *Aleyrodes citri*,[3] and still more recently it received, through Mr. August Mayer, in charge of plant-introduction garden, and through the California state commission of horticulture, specimens of orange leaves infested with what Prof. Quaintance has identified as this species from different parts of China and Japan.

The occurrence of the citrus white fly in India (northwestern Himalayas) has recently been established by Prof. Quaintance, who has compared Maskell's *A. aurantii*, collected in the region mentioned

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[1] Proceedings of the Entomological Society of Washington, vol. 9, pp. 121–122, 1908.

[2] Specimens of the species present at Bakersfield were examined by the senior author at the California State Insectary at Sacramento and found to be the cloudy-winged white fly (*A. nubifera*).

[3] Proceedings of the Entomological Society of Washington, vol. 8, Nos. 3–4, p. 107.

above, with *A. citri,* and failing to find any differences in the egg and pupal stages found it necessary to regard the name given by Maskell as a synonym of that given by Riley and Howard.

The citrus white fly does not occur in Cuba, so far as known, although it is not unlikely to be found there, since there have been heavy shipments of nursery stock from infested citrus nurseries in Florida to that country during the last few years.

## FOOD PLANTS.

### AUTHENTIC AND QUESTIONABLE RECORDS.

The separation as distinct species of two forms formerly considered as belonging to the species *Aleyrodes citri* makes it necessary that all of the reported food plants of the citrus white fly be verified. Nearly 60 species of the genus Aleyrodes have been recorded for North America. Of these less than 20 have been described in the first larval stage in a manner which distinguishes them, although when carefully studied this stage has been found to have striking specific characters. The second and third larval stages rarely possess distinguishing characters. The fourth or pupal stage, or the empty pupa case, is used as the basis of specific descriptions in the Aleyrodidæ, but even in this stage a careful microscopic examination is usually necessary to positively determine the species. Good specific distinctions in the adult stage have been found only in a few species, and even those entomologists who have made a specialty of the Aleyrodidæ do not attempt to distinguish the different species in this stage. It is obvious, therefore, that a list of food plants should properly include only those verified by entomologists, with determinations of the species made since the status of the two most abundant citrus-infesting species of Aleyrodes has been fully recognized. Dr. E. W. Berger has recently arranged the full list of food plants and reported food plants in a graphic manner, separating the list into two classes according to the degree of preference, and each class is subdivided into native and introduced species. This method of grouping the food plants is here adopted (see Table IV) with the transposition of the lilac and coffee from class II to class I and omitting certain reported food plants in order to restrict the list to include only positive records, leaving the others for a separate discussion. Dr. Berger has recently discovered the citrus white fly on wild olive, and has also verified Prof. Gossard's report of the citrus white fly on *Viburnum nudum.* Both of these food plants, together with the green ash, will eventually be found to be subject to heavy infestation and be placed in class I.

TABLE IV.—*Definitely known food plants of the citrus white fly (Aleyrodes citri).*

CLASS I. PREFERRED.

Introduced:

1. Citrus (all species cultivated in America).
2. China tree (*Melia azedarach*).
3. Umbrella China tree (*Melia azedarach umbraculifera*).
4. Cape jessamine (*Gardenia jasminoides*).
5. Privets (*Ligustrum* spp.).
6. Japan persimmon (*Diospyros kaki*).
7. Lilac (*Syringa* sp.).
8. Coffee (*Coffea arabica*).

Native:

9. Prickly ash (*Xanthoxylum clava-herculis*).
10. Wild persimmon (*Diospyros virginiana*).

CLASS II. OCCASIONALLY INFESTED.

Introduced:

11. Allamanda (*Allamanda neriifolia*).
12. Cultivated pear (*Pyrus* spp.).
13. Banana shrub (*Magnolia fuscatum*).
14. Pomegranate (*Punica granatum*).

Native:

15. Smilax (*Smilax* sp.).
16. Cherry laurel (*Prunus laurocerasus*).
17. Wild olive or devilwood (*Osmanthus americanus*).
18. Viburnum (*Viburnum nudum*).
19. Green ash (*Fraxinus lanceolata*).

In addition to those in the foregoing list [1] there are several plants reported as food plants of the citrus white fly which, while probably true food plants, can not consistently be included in the recognized list until the observations have been repeated and the infesting species positively identified. In some instances where eggs or larvæ have been found there is doubt as to whether the white fly could develop to maturity on the plants in question. Plants upon which the insect is unable to develop to maturity can not properly be considered true food plants. The following is the list of plants reported as food plants, but which in each case require further observations either as regards the ability of the insect to reach maturity thereon or as regards the species of white fly concerned, in view of the recent separation of *A. citri* and *A. nubifera:* Water oak, reported by Prof. A. L. Quaintance; *Ficus altissima*, *Ficus* sp. (from Costa Rica), and scrub palmetto, reported by Prof. H. A. Gossard; honeysuckle and blackberry, reported by Dr. E. H. Sellards; oleander, reported by

[1] In addition to those already mentioned as being food plants in Florida, the following plants are on record at the State insectary at Sacramento, Cal., as food plants of the citrus white fly observed at Marysville and Oroville by agents of the State commission of horticulture: English ivy (*Hedera helix*), yellow jessamine (*Jasminum odoratissimum*), *Ficus macrophylla*, bay (*Laurus nobilis*), tree of Heaven (*Ailanthus glandulosa*), and crape myrtle (*Myrtus lagerstrœmia*). Information concerning the authorities for the plants listed is not available.

the senior author of the present publication; camellia, reported by Dr. E. W. Berger. In the case of the last two plants mentioned the uncertainty as to their proper standing is on the possibility of the insect reaching maturity thereon and not on the identity of the infesting species.

The present status of the plants which have heretofore been listed by entomologists as food plants of the citrus white fly is shown in the foregoing paragraphs. There are doubtless numerous additional introduced species and a few additional native species of plants occurring in the United States which serve or are capable of serving as food plants of the citrus white fly, but for the reasons connected with the identification of the insects, stated in the opening paragraph under the subject of food plants, reports of food plants other than those included in classes I and II should never be credited unless verified by or made by an entomologist. There are no important food plants occurring in the Gulf coast region omitted from this list, and future additions to the list probably will be of little significance economically as affecting the control of the pest. There is a widespread belief that many other common trees, shrubs, and vines in Florida are food plants of the citrus white fly, but the correctness or falsity of this belief can be readily ascertained in the case of the individual plants suspected by submitting specimens of the foliage and of the infesting insect to the Bureau of Entomology or to the State experiment station.

There are three common causes for erroneous reports concerning citrus white-fly food plants. The first is the presence of sooty mold on many plants, due to other honeydew-secreting insects, such as aphides, scale insects, and mealy bugs. The insects themselves are not seen in this case and the mistaken idea is due to ignorance of the fact that other insects than the citrus white fly excrete honeydew on which the same species of sooty mold fungus thrives. The second cause for erroneous reports in this respect is the misidentification of the insect concerned. The necessity for the identification of the infesting insect by an entomologist has been discussed. The third cause is the frequent occurrence of the adult citrus white fly on the foliage of plants upon which it does not breed and upon which it seldom or never deposits an egg. In the course of the present investigation by the Bureau of Entomology several trees and shrubs have been thoroughly tested as possible food plants by cage experiments, and observations have been made on these and other plants, showing that if it is possible for the citrus white fly to develop on one of them, it is, at the most, of too rare occurrence to be of any significance. Cage tests have been made with oak (*Quercus brevifolia*), Magnolia (*Magnolia fœtida*), blackberry (*Rubus* spp.), Laurel cherry or mock olive (*Prunus caroliniana*), and cultivated figs (*Ficus carica*) and crape myrtle (*Myrtus lagertræmia*). In each case a rearing cage (Pl. VII)

was attached to the end of a branch covering new growth and from 50 to 100 adults of *A. citri* were confined therein. Except in the case of the blackberry, in which no observation was made on the point, the adults were noted as resting contentedly and apparently feeding on the leaves for one or two days after being confined. In every case, however, all the adults were dead on the fourth day after confinement on the plants noted, although check lots of adults collected at the same time but confined on branches of citrus trees lived for a normal period. No eggs were deposited in any of the tests, although the check lots deposited eggs on the citrus leaves in a normal manner.

Each of the five plants tested with the cage experiments have in addition been subjected to very careful examinations by the writers under such circumstances that the opportunities for infestation by the citrus white fly were at their best. In addition, particular attention has been given to examinations of species of oaks (*Quercus* spp.) and bays (*Persea* spp.), guavas (*Psidium* spp.) and mulberries (*Morus* spp.), when located near, and in some cases with branches intermingling with infested citrus or other favorite food plants.

### Economic Significance of Food Plants, and Interrelationship Between Food Plants and Insects.

Entomologists familiar with the present white-fly situation agree in their conclusion that a requisite for satisfactory control of this pest is proper attention to food plants other than citrus fruit trees. Mr. H. G. Hubbard, who was a well-known authority on orange insects, being a special agent of the Bureau of Entomology, was a strong advocate of destroying food plants of the white fly that were of no value. Dr. Sellards, formerly entomologist at the Florida Experiment Station, Dr. Berger, the present entomologist, Prof. P. H. Rolfs, director of the Florida Experiment Station, and the authors have each emphasized the importance of the relation of the various food plants to white-fly control.

The following paragraph from the senior author's bulletin on the subject of fumigation for the citrus white fly [1] states in a general way the situation in this respect as viewed by entomologists who have investigated the white fly:

> The presence of food plants of the white fly other than citrus trees, in citrus fruit-growing sections, constitutes a serious menace and in itself often prevents successful results from remedial work. Fortunately the list of food plants is limited, and the greater number of those thus far recorded is subject to infestation only when located near or in the midst of heavily infested citrus groves. The food plants which are of most importance in connection with the white-fly control are the chinaberry trees, privets, and cape jessamine, and these—except for the last, in certain sections where grown for commercial purposes—can be eradicated readily, or their infestation may be prevented where community interests precede those of the individual in controlling

[1] Bulletin 76, Bureau of Entomology, U. S. Department of Agriculture, pp. 9–10.

public sentiment. These food plants favor the rapid dissemination of the white fly from centers of infestation and their successful establishment in uninfested localities. They seriously interfere with the success of fumigation, as well as of all other remedial measures, by furnishing a favored breeding place where the white fly can regain its usual abundance in a much shorter time than would be the case if it were entirely dependent upon citrus fruit trees for its food supply. The plants mentioned, together with *Citrus trifoliata* (except where used in nurseries), and all abandoned and useless citrus trees should be condemned as public nuisances and destroyed in all communities where citrus fruit growing is an important industry.

Not only is a knowledge of the relation of the various noncitrus food plants to white-fly injury of great importance, but it is also of considerable importance to growers to know the capability of the insect for multiplying on the different citrus fruit trees in order that advantage may be taken of it in the arrangement of new groves and the improvement of old groves.

### CITRUS.

It is a matter of common observation that injury from the white fly is most marked on citrus fruits of the Mandarin group. This group includes the Tangerine, Satsuma, and King of Siam. The sweet oranges are next to the mandarins in this respect, followed by the kumquats and grapefruits.

The relatively less injury to grapefruit by the citrus white fly (*A. citri*) is sometimes obscured by the presence of *A. nubifera*. Blackening of foliage and fruit by the citrus white fly is more noticeable on grapefruit trees when they are surrounded by or are otherwise unfavorably located in respect to oranges or tangerines. Solid blocks of grapefruit trees rarely show more than slight effects of white-fly infestation when only the citrus white fly is present. An example of this is the Manavista Grove at Manavista, Manatee County, Fla. This grove consists of 22,000 grapefruit trees, and appreciable blackening of the foliage is rarely seen except occasionally where orange groves adjoin. Only one record, based on actual examination of leaves, illustrating the difference in the degree of infestation of adjoining blocks of grapefruit and orange trees is available. The grapefruit block consisted of about 400 trees located immediately north of a block of 200 or 300 orange trees and separated on the west by a public road from a grove of about 800 orange trees. On April 23, 1909, after practically all the overwintering pupæ had matured, an examination of 100 or more leaves collected at random from each grove, counting the pupa cases, showed an average of 8 insects that had reached maturity on the grapefruit leaves, 27 on the orange leaves of the block south, and 56 on the orange leaves of the block west. No studies have been made to determine the different degrees of susceptibility to white-fly injury among the different varieties of grapefruit, but the Royal variety appears to be more

nearly immune than any other of those commonly grown. This was first pointed out by Mr. F. D. Waite, of Palmetto, Fla. In this connection it should be noted that the Royal variety in its general characteristics is not a typical grapefruit.

The reason for the partial immunity of grapefruit trees to white-fly injury is as yet obscure. Several observations on grapefruit and orange trees growing side by side give no basis for the supposition that it is a matter of food-plant preferences of the adult flies. In some cases the differences in the amount of new growth must be taken into consideration. Counts of adults, pupa cases, and hatched eggs of the citrus white fly on alternating grapefruit and orange trees, six in all, located on the laboratory grounds at Orlando, were made on June 4, 1909, when no new growth was present on the trees. The leaves were selected at random and, with the exception of a few upon which adults were counted, they represented the spring growth of 1909. The difference between the number of the adults on 500 grapefruit and 500 orange leaves, 87 and 104, respectively, is not as great as would be expected, considering the much greater number of insects that had matured on the orange up to the time of the examination. There were about twenty times as many pupa cases on the 100 orange leaves as on the 100 grapefruit leaves, or 6 and 120, respectively. This was offset by the presence of about three times as many live pupæ on 10 grapefruit as on 10 orange leaves, 41 and 14, respectively, making the sum of the pupa cases and live pupæ 4.16 per leaf in the case of the grapefruit and 2.6 per leaf in the case of the orange. This is about the same proportion as the number of hatched eggs on the two food plants. The condition of the leaves, as shown by this data, fails to indicate any cause for the partial immunity of grapefruit trees.

The examinations by Mr. W. W. Yothers of two leaves picked at random from each tree in a small isolated grove consisting of 41 grapefruit and 28 tangerine trees gave rather striking figures, showing more rapid multiplication of the citrus white fly on the latter than on the former. The first examination was made on November 4, 1908, and the second on June 8, 1909. On the former date the average number of live and dead white-fly larvæ and pupæ per leaf was 31.9 on the grapefruit and 96.2 on the tangerine, 16.6 and 80.9, respectively, being alive. During the winter a series of fumigating experiments reduced the numbers of the white fly so that at the second examination the number per leaf was 1.1 on the grapefruit and 2.25 on the tangerine. The arrangement of the two kinds of trees in the grove was such that they had equal chances of becoming reinfested by the insects which escaped the effects of the experimental tests.

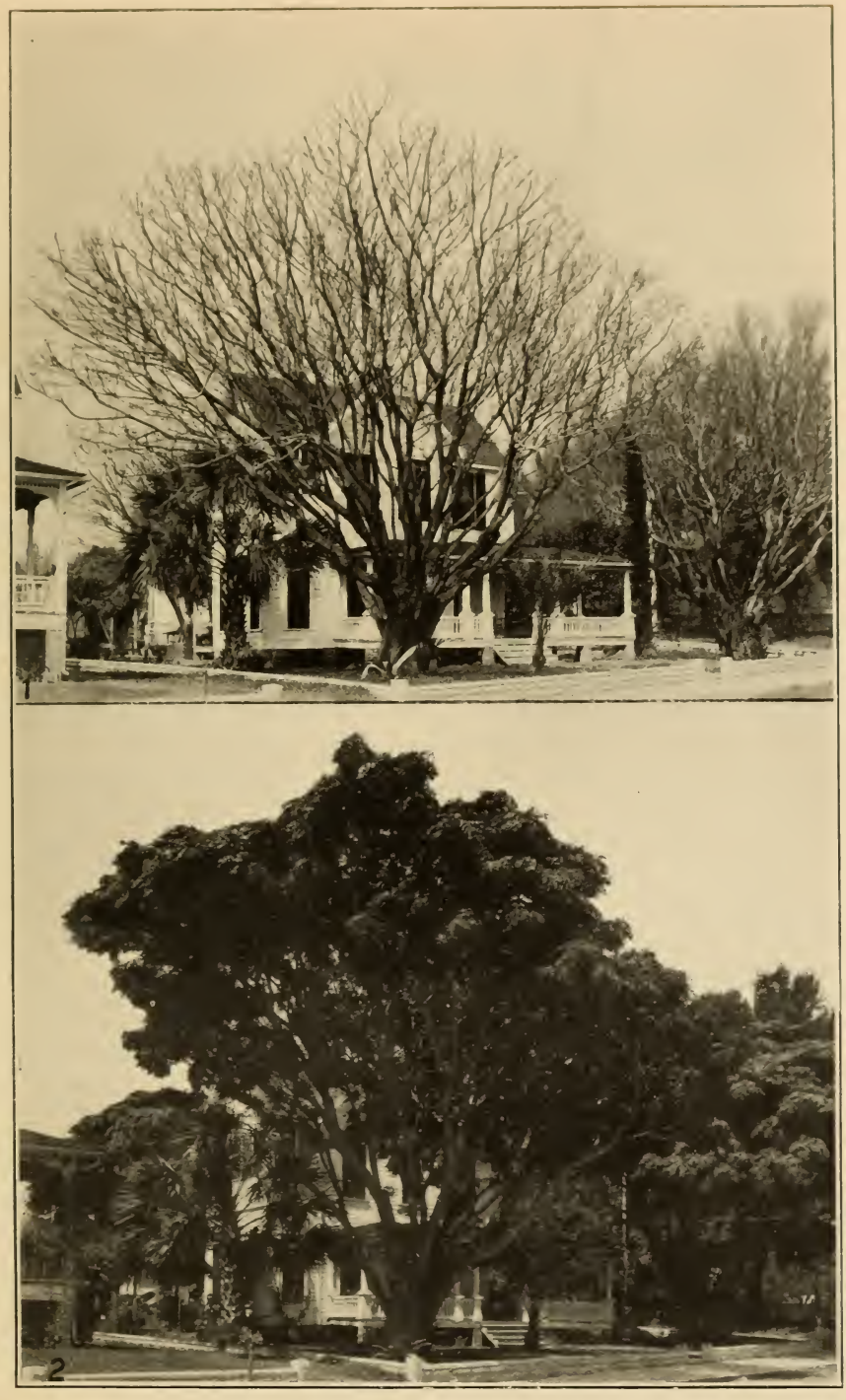
The difference in the degree of injury between orange and tangerine trees is less marked than between tangerine and grapefruit or orange and grapefruit, but the difference is nevertheless usually quite noticeable. The practical application of this difference in the degree of adaptation of the citrus white fly to the various citrus food plants will be discussed in a forthcoming bulletin dealing with the artificial control of the white fly.

### CHINA TREES AND UMBRELLA TREES.

While China trees (Pl. IV) and umbrella China trees (Pl. V), when grown for shade and ornamental purposes, are, as has been pointed out, very injurious to citrus fruit-growing interests, the investigation of the utility of these plants as trap foods gives an increased importance to a definite knowledge concerning them as citrus white-fly food plants. Their injuriousness to citrus growers is very clear to professional entomologists, but not as generally appreciated by the citrus growers themselves as is desirable.

The umbrella tree is recognized by botanists as a variety of the China tree. This variety is the one most commonly grown except in a few localities, and observations reported herein specifically refer to it and not to the China tree. The latter tree has, however, been under observation by the authors, and no noticeable difference has been observed between the two trees in their relation to the citrus white fly, and the data and observations are in the main fully as applicable to the one as to the other.

The numbers of the white fly which mature on individual umbrella trees have been estimated in three instances and found to range between 25,000,000 and 50,000,000 where trees are favorably located with respect to nondeciduous food plants. Examinations were made by selecting 10 or more leaves at random and from each selecting a leaflet which appeared to represent the average condition of all the leaflets composing the leaf. In two instances it was found that the infestation was fully as great toward the top of the tree as on the lower parts. In one instance an extensive examination of different parts of an infested umbrella tree showed a decrease from lower branches to top branches of 50 per cent. In order to be fully conservative, this percentage has been used as the basis of the calculations, making the average infestation throughout the tree 75 per cent of the infestation of the leaves of the lower branches. Full-grown leaves were found to consist of about eighty-two leaflets. Complete records were made of eggs and of live and dead larvæ and pupæ, but only a part of this data will be presented. The estimates and counts of both leaves and insects in the case of the first tree were made by the senior author; in the cases of the second and third trees the estimates of the number of leaves per tree represent the average




THE CHINA TREE.

Fig. 1.—China tree defoliated during winter. Fig. 2.—Same tree in full foliage in summer. (Original.)

THE UMBRELLA CHINA TREE.

Fig. 1.—Leaflet of umbrella China tree, showing infestation by *A. citri*. Fig. 2.—Umbrella China tree with orange tree in rear of house. (Original.)

of three estimates—one by the senior author, one by the junior author, and one by Mr. W. W. Yothers. The counts and estimates of insects were made by the senior author in the second instance and by the junior author in the third. The data obtained in these examinations bearing on the number of insects the umbrella trees are capable of maturing are given in Table V.

TABLE V.—*Number of citrus white flies developing on umbrella China trees.*

| Tree. | Date of examination. | Estimated number of leaves on tree. | Number of pupa cases per leaf. | Number of live pupæ per leaf. | Estimated number of insects matured on tree. | Estimated number of larvæ and pupæ alive at time of examination. |
|---|---|---|---|---|---|---|
| 1 | Oct. 28, 1906 | 20,000 | 2,478 | 4.1 | 49,560,000 | 82,000 |
| 2 | Aug. 19, 1908 | 25,000 | 1,910 | 13.2 | 47,762,000 | 330,000 |
| 3 | Aug. 25, 1908 | 12,000 | 2,230 | 4.0 | 26,760,000 | 58,800 |

The three trees examined are not in any way exceptional as regards the degree of infestation, but may be considered as representative of the condition of China trees and umbrella China trees in localities where the citrus white fly is established. Tree No. 1 was located by the roadside near a 5-acre grove of newly bearing budded orange and grapefruit trees which were lightly infested by the white fly and on which it is estimated that not over 100,000 insects could have matured on any one tree during the season. Tree No. 2 was located most unfavorably for a heavy infestation, standing in a vacant lot in the business section of Orlando and having its source of citrus white-fly infestation in the spring almost entirely restricted to two neglected and worthless orange trees of small size growing within a radius of 100 feet. Tree No. 3 was located in front of the laboratory at Orlando, with 36 orange and grapefruit trees on the grounds. The least conservative of the authors' estimates would place the number of white flies which matured on any one of these citrus trees during the year 1908 as not over 500,000, with the average of the 36 trees at about one-half this number. It is estimated, therefore, that the one umbrella tree produced upward of three times as many adult citrus white flies during the year 1908 as the 36 citrus trees on the laboratory grounds combined. The important relation of the remarkable multiplication of the citrus white fly on China and umbrella trees to the spread of the pest will be discussed under the heading "Spread."

Two new points of importance have been established by the present investigations in regard to umbrella China trees as citrus white fly food plants. First, this insect shows in one respect a greater degree of adaptation to this food plant than to citrus plants, as shown by the very low rate of mortality in the immature stages. Table VI gives the data obtained by five counts made at Orlando, Fla., during these investigations.

TABLE VI.—*Mortality of citrus white fly on umbrella China tree leaves.*

| Date. | Pupa cases. | Live larvæ and pupæ. | Dead larvæ and pupæ. | Mortality. |
|---|---|---|---|---|
| | | | | *Per cent.* |
| Oct. 28, 1906... | 806 | 1 | 111 | 12.0 |
| July 8, 1908.... | 497 | 338 | 192 | 18.7 |
| July 21, 1908... | 113 | 256 | 51 | 12.1 |
| Aug. 19, 1908.. | 232 | 49 | 152 | 35.1 |
| Aug. 25, 1908.. | 312 | 169 | 70 | 13.4 |
| Total... | 1,960 | 813 | 596 | 18.2 |

The record made on August 19, 1908, showing the highest percentage of dead stages of the white fly, was based upon 10 leaflets selected from a single leaf and is not considered so typical of the condition throughout the tree examined as is the case in the other records. In contrast to the low mortality records as shown by the insect forms present on the leaves of the umbrella trees, 26 records of mortality in citrus groves gave an average of 57.9 per cent dead on the leaves. These records were based on the examination of about 2,000 leaves and over 100,000 white-fly forms. It should be noted that the mortality in the above records is based on the number of live and dead larvæ and pupæ, and of pupa cases present on the leaves at the times of the examinations. The actual mortality would be represented by the difference between the total live larvæ, live pupæ, and pupa cases and the number of hatched eggs. On umbrella China tree leaves this difference is slight and represented for the most part by the number of dead larvæ and pupæ found on the leaves. In the case of the citrus trees, on the other hand, the number of citrus white-fly forms on the leaves ordinarily represents only from 25 to 30 per cent of the total number of eggs deposited. This disappearance from the leaves is discussed elsewhere. Its significance in this connection is that the actual mortality on citrus leaves is much higher than the average per leaf of 57.9 would indicate. The citrus white fly forms in the leaves show a mortality on the umbrella tree amounting to only one-third of the mortality on citrus trees. The consideration of the number of hatched eggs as a basis for mortality estimates would reduce this to about one-fifth. The figures refer to citrus groves where the citrus white fly is well established. In newly infested groves the rate of mortality is much smaller as a rule.

The second important point established in the course of the investigations reported herein is that adult citrus white flies are so strongly attracted by growing leaves of umbrella trees that under certain conditions with umbrella and citrus trees growing side by side more adults collect on three or four umbrella leaves than are present on entire citrus trees of medium size.

It has been frequently observed that when the citrus white fly is first becoming established in a grove, if China trees or umbrella China trees are near, adults often can be found on these when none can be found on surrounding or intervening citrus trees. In order to obtain a more definite idea of the relative attractiveness of umbrella China trees and citrus trees, 4 records were made by the senior author on the laboratory grounds (fig. 2) at Orlando. In observation No. 1, the count on citrus was made on 4 trees, viz, 4 A, 4 B, 4 C, and 5 C, and the observations on umbrella China trees were made on 2 small trees located about 6 and 20 feet, respectively, southwest of 4 A. These umbrella China trees were slender 2-year-old growths about 4 and 5 feet high and together bearing about 40 leaves.

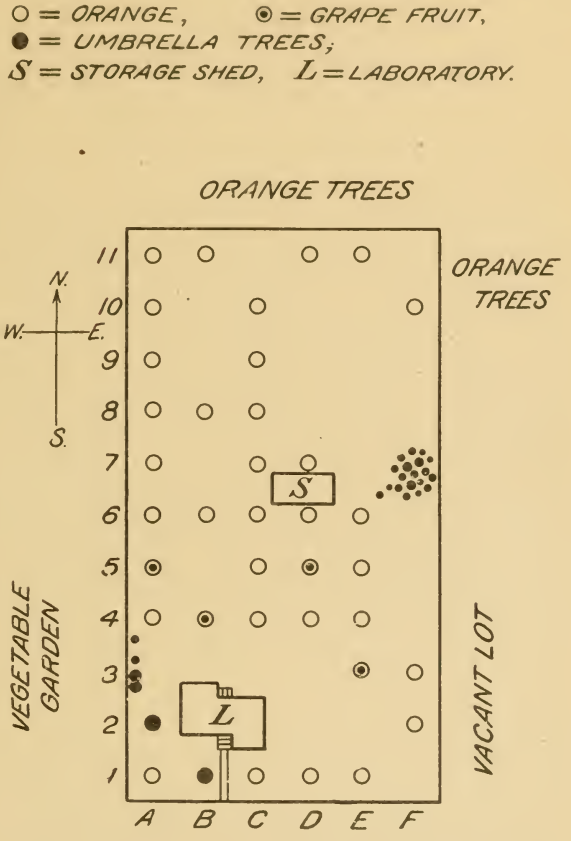



FIG. 2.—Diagram of the laboratory grounds at Orlando, Fla. (Original.)

Observation No. 2 was made on grapefruit and orange trees E 6, E 5, E 4, D 5, D 4, and F 3 and two stems of the umbrella China tree cluster in space F 7 nearest to tree E 6. Observation No. 3 was made on tree A 4 and the nearest umbrella China tree sapling. This latter had been defoliated since observation No. 1 was made. Observation No. 4 was made on citrus trees D 7, E 6, E 5, E 4, E 3, and F 3 and on two stems of the umbrella cluster which had been defoliated since observation No. 2. The data obtained by the four observations are given in Table VII.

TABLE VII.—*Relative attractiveness to the citrus white fly of foliage of umbrella China trees and citrus trees.*

| Observation No. | Date. | Citrus trees. | | | Umbrella China-trees. | | |
|---|---|---|---|---|---|---|---|
| | | Number of minutes. | Number of adults counted. | Number of trees examined. | Number of minutes. | Number of adults counted. | Approximate number of leaves examined. |
| | 1909. | | | | | | |
| 1..... | May 18 | 5 | 257 | 4 | 5 | 508 | 25 |
| 2..... | ...do .... | 5 | 19 | 6 | 5 | 615 | 30 |
| 3..... | June 11 | 3 | 34 | 1 | 3 | 477 | 6 |
| 4..... | ...do .... | 5 | 52 | 6 | 5 | 830 | 15 |
| | Total . | 18 | 362 | 17 | 18 | 2,427 | 76 |

In all, 2,789 specimens were counted, of which 88 per cent were on umbrella China tree leaves. It was estimated that in each record on a citrus tree approximately 2,000 leaves were examined, making 34,000 in all. The individual leaflets composing the 76 umbrella-tree leaves numbered approximately 6,000. For practical purposes these leaflets are more comparable to the citrus leaves although the latter have on the average fully twice as much surface. With this basis for comparison it can be figured from the above data that there was about one adult white fly per 100 leaves on the citrus trees while there were about 40 adults per 100 leaflets on the umbrella trees.

As has been indicated, the difference between the number of China-tree leaves in numbers 3 and 1 and between 4 and 2, respectively, represents the oldest spring growth, which was removed on May 24, leaving only a few growing leaves. No direct comparison was made between the attractiveness of the older growth of citrus and umbrella trees but apparently there is no striking difference between the two food plants in this respect. New watershoots were present on the citrus trees on both dates when observations were made but only in the case of one tree, 4 A, were many adults found on this growth. In observation No. 1 on the tree mentioned (4 A) 200 adults were counted on two watershoots. Except for watershoots there was no new growth on any of the citrus trees.

At Orlando the umbrella trees usually start to put on new foliage in the spring before new growth appears on citrus trees. As a consequence China and umbrella trees located near infested citrus trees receive large numbers of adults of the citrus white fly which migrate in search of attractive food. On February 22, 1909, the authors noted on the laboratory grounds that the shoots of the umbrella tree were beginning to put out new growth, the leaves not fully unfolded. The citrus white fly was found scatteringly on the umbrella leaves but on citrus trees specimens could be found only after careful search.

On March 27, 1907, near the laboratory, then located in the grove of Mr. J. M. Cheney, a striking example of the attractiveness of the umbrella tree was observed. The tree referred to was about 25 feet high and the leaves which were on the average only about half developed were estimated to number 5,000. Ten leaves were selected at random within 10 feet of the ground and the number of adults and eggs was counted, the former numbering 5.3 per leaf on the average and the latter 160 per leaf. The tree was cut down and an examination of the topmost leaves showed an average of 186 eggs per leaf; the adults, being disturbed, were not counted, but judging from the number of eggs present they evidently were more rather than less numerous than on leaves near the ground. Considering the average of 5.3 per leaf, however, the total number of adults on the tree would be estimated at 26,500, and at 160 eggs per leaf the number of eggs deposited would be estimated at 800,000. At the time of this observation about 50 per cent of the insects which overwintered on the citrus leaves had matured. The citrus white fly had been much reduced throughout the grove, in some sections by unexplained influences, in others by these influences and fumigation experiments combined, and on a few tangerine trees by a fungus parasite, red Aschersonia. The location of the umbrella tree did not seem to be a favorable one as regards opportunities for white-fly infestation, but examination showed the infestation to be at least 100 times greater, as regards the number of adults present, than on any citrus tree in the grove. There were, in fact, too few eggs deposited on the leaves of the citrus trees to allow of sufficient multiplication of the white fly during the season to cause any blackening of foliage or fruit.

### CAPE JESSAMINE.

The cape jessamine has long been recognized not only as a favorite food plant of the citrus white fly, but as especially important economically on account of its retaining its foliage throughout the year. From a statement by Riley and Howard[1] concerning observations by Mr. H. G. Hubbard and statements by Dr. H. J. Webber, Dr. Montgomery, and others in the discussions on the citrus white fly at a meeting of the Florida State Horticultural Society,[2] it appears that the freezes of December, 1904, and February, 1905, which completely defoliated citrus trees when not especially protected, failed to defoliate cape jessamines. In many localities it is probable that this food plant was responsible for the survival of the white fly at the time referred to. According to Dr. Sellards,[3] temperatures as low as

[1] Insect Life, vol. 7, p. 282.

[2] Proceedings of the Florida State Horticultural Society, 1896, p. 78.

[3] Press Bulletin 56, Florida Agricultural Experiment Station, p. 2.

16° above zero at Lake City, between January 26 and January 29, 1905, failed to defoliate cape jessamine.

Except where grown for commercial purposes, as is the case at Alvin, Tex., where the blooms are shipped to northern markets, or where grown in nurseries, cape jessamines have not been observed growing in sufficient abundance to materially affect near-by citrus trees in sections where the white fly is already established. If overlooked in connection with the fumigation of citrus groves or defoliation of citrus trees by cold, cape jessamines might become a serious hindrance in the control of the white fly. The greatest economic importance of the cape jessamine as a food plant lies in the great danger it presents as a distributer of the white fly. This will be referred to again under the subject of methods of spread.

The subject of the adoption of the cape jessamine by the citrus white fly is not of sufficient importance to have been given more than incidental consideration. In general the degree of adoption seems to be less than is the case with the umbrella and China trees. On November 17, 1907, an examination made of 30 leaves picked at random from both old and new growth of a cape jessamine which appeared to be in an ordinary condition of infestation as observed when growing near infested citrus trees showed that there existed an average of 45.1 forms per leaf.

The extensive growth of cape jessamines, or gardenias, as the blooms are sometimes called, for commercial purposes is known to the authors and occasions a conflict of interests only in Alvin, Tex. From the orange grower's standpoint this, at the most, applies to a location adjoining an orange grove where the citrus white fly is uncontrolled. Fortunately, however, for the citrus growers, it is of great importance to the success of the florist's business that the white fly be kept in subjection in gardenias.

### PRIVET HEDGES.

Privet hedges are not uncommon in citrus-growing sections, and heavy infestations by the citrus white fly occur in parts of Georgia and South Carolina, where no citrus trees are grown. As a food plant the privets are of economic interest in the same respects as is the cape jessamine, but they are more extensively grown and of proportionally greater importance. No studies have been made of the degree of adaptation and attractiveness, but the several species of privet observed in infested localities have shown the propriety of classing them with citrus, China trees, umbrella China trees, cape jessamine, and other preferred food plants. The senior author observed a migration of adults from privet hedges in Victoria, Tex., in the summer of 1904, which indicated that a hedge of this material

might well be compared in its injurious influence on citrus-growing interests to one or more umbrella or China trees. The privet, like the cape jessamine, is hardy, and the disadvantages of the former in this connection are the same as those mentioned in discussing the latter food plant.

### JAPANESE AND WILD PERSIMMONS.

Japanese and wild persimmons are attractive to the citrus white fly early in the season, but appear to be very little or not at all so late in the season. Being deciduous, their economic importance as white fly food plants is proportionally small. Under normal conditions the Japanese persimmons appear much more attractive to the citrus white fly than citrus trees. These conditions have not been investigated, but they are probably dependent upon the appearance of new growth in the spring a little earlier on persimmon than on citrus. On June 16, 1909, an examination of a large bearing persimmon tree surrounded by citrus nursery trees and bearing citrus trees of different kinds showed that the first spring growth of the persimmon was much more attractive to the first brood of adults than were the citrus trees. The second brood of adults, however, found the persimmon comparatively unattractive and showed a marked preference for the citrus trees. The earliest citrus growth of the spring had become fully matured, and no new growth appeared until after the second brood of adults had practically disappeared. The comparative condition of infestation is shown by counts made on leaves picked at random from the persimmon tree and from the surrounding citrus trees, including the sweet orange, sour orange, tangerine, and grapefruit. The average infestation with first-generation forms of the citrus white fly on 25 leaves each of persimmon and citrus was in the ratio of 10.9 to 1.3, while that of the same number of leaves by the second generation was in the ratio of no forms on the persimmon leaves as compared with 191 on the citrus, thus showing the great preference of the second generation of adults for citrus growth.

Neither the Japanese nor the wild persimmons are usually infested by the citrus white fly to the extent of causing noticeable blackening from sooty mold. The infestation, however, might be between from five to ten times as great as on the leaves from the trees referred to above without producing this result. Small wild persimmon bushes have been observed in a growing condition at the time the adults of the second brood are on the wing, and at such times they sometimes appear to be very attractive as food plants. Mr. W. W. Yothers has observed near Hawthorn, Fla., on April 29, 1909, the citrus white fly on wild persimmon bushes growing in pine woods at distances upward to one-

fourth of a mile from any citrus grove, and the junior author has made similar observations along roadsides near Orlando, Fla., in June, 1909, the insects being in the adult stage only in this latter case. On the other hand, the senior author noted on June 18, 1909, that wild persimmon bushes growing in a vacant lot with China trees and abandoned citrus trees were only very slightly infested, although the citrus trees and the China trees were heavily infested. The wild persimmon had made vigorous growth, but its white-fly infestation consisted of less than 100 eggs per leaf and an occasional adult. The examination of leaves of the China tree showed hundreds of pupæ and pupa cases per leaf, with a few adults and newly deposited eggs. The old citrus leaves bore many larvæ, pupæ, and pupa cases, and the new leaves bore hundreds of unhatched eggs. The wild persimmon bush was as favorably located with respect to citrus trees as was the China tree. Notwithstanding the exceptions noted in degree of attractiveness, the Japanese and the wild persimmons very evidently rank well below citrus trees, China trees, and umbrella China trees.

In so far as observed the persimmons have little effect on the control of the citrus white fly, but in special cases they may rank as important food plants. The fact that the Japanese persimmon is a producer of fruit of some commercial value makes its ordinary lightness of infestation a matter of gratification. The wild persimmon, on the other hand, is of practically no value either for shade or fruit, and can easily be destroyed where advisable.

### LILAC.

Lilac is not commonly grown in the citrus-growing regions of the Gulf States, and on this account, so far as observed, presents no element of menace to orange groves. In company with all of the ornamental plants listed as preferred food plants this one must be considered, however, as undesirable for introduction and growing in citrus-growing regions.

### PRICKLY ASH.

Belonging to the family Rutaceæ, to which the genus Citrus also belongs, it is not strange that the prickly ash is a favorite food plant of the citrus white fly. This plant seems to be highly attractive to the adult flies, frequently being observed infested with more adults than many near-by citrus trees combined. The prickly ash is common in Florida and in some localities, where growing in abundance along roadsides, it constitutes a distinct menace to citrus groves through its connection with the spread of the white fly from city and town to country and from grove to grove.

COFFEE.

Dr. E. W. Berger has reported having observed a coffee tree thoroughly infested with as many eggs on its leaves as citrus leaves may have. This food plant is too rarely grown in the Gulf States in orange-growing regions to be of any importance economically as a white-fly food plant.

OCCASIONALLY INFESTED FOOD PLANTS.

The plants listed in Class II as a whole are of very little importance as regards their bearing on white-fly control. Banana shrub, cherry laurel, and cultivated pear might well be considered in a third class for rarely infested plants. Although not uncommon, their attraction for the citrus white fly is so slight as to make it safe to ignore them except in the matter of introducing the fly on them into noninfested districts. In unpublished notes Dr. Berger has recorded the wild olive as a food plant. He has observed the wild olive infested in comparatively isolated places. The junior author has observed wild olive heavily infested in Charleston, S. C., and in several places in Orange County, Fla. The wild olive, being an evergreen, if neglected may prove to be of considerable importance as a food plant when growing in abundance near a fumigated grove or when citrus trees have been defoliated by cold.

Dr. Berger has recorded pomegranate, allamanda, and smilax as food plants, and has verified Prof. Gossard's record of *Viburnum nudum* as a food plant of the citrus white fly. The positions of these plants as regards their attractiveness to the citrus white fly has not been fully determined, and further observations will perhaps show one or more of them to be of fully as high if not of higher rank in this respect than the persimmons. In general, however, like the coffee and lilac of Class I, they are not of sufficiently common occurrence in the Gulf coast citrus-growing regions to be of much economic importance as citrus white-fly food plants.

SPREAD IN THE UNITED STATES.

There is seldom positive evidence in regard to the means by which the citrus white fly has become established in a previously noninfested grove or locality. Such direct observations, however, as it is possible to make, aided by strong circumstantial evidence, give us a sufficient knowledge of the methods of spread to show the advisability of certain restrictive measures.

Checks on Successful Establishments.

Fortunately the chances are greatly against the successful establishment of the citrus white fly in a previously uninfested locality, which is outside the limits affected by large numbers of migrating

adults. If this were not so the pest would have become established in every grove of the State long before the present time. Except for spread by direct flight and on nursery trees and ornamental plants, the chances are against more than a few insects being introduced into a particular grove by any of the other methods discussed hereafter.

In the case of a single adult there are two chances in three that it would be of the reproductive sex. If, as would be probable, the specimen were a female, there would be about one chance in three that it would not have been fertilized. In this case the second generation of adults would all be males, as shown by the observations recorded under the subject of Parthenogenesis. This would, of course, end the infestation directly due to the single specimen introduced, as the original female would have died several weeks before the first male matured. In case the originally introduced specimen were a female and fertile the chances of a male appearing among the second generation are not definitely known, but are with little doubt only small. The chances of such a male appearing at a favorable time to meet with and to fertilize a female of the same parentage are practically negligible, though possible as a result of the great variation in the length of the life cycle as recorded under life history. The third generation would, therefore, in all probability, be all males, and the infestation ended. The chances that a single adult specimen introduced into an isolated grove or into a previously noninfested community would successfully establish a permanent infestation are extremely small. The chances are only slightly increased by an increase to 5 or even 10 in the number of adults originally introduced into a single grove.

From the foregoing considerations it is evident that two or more distinct introductions of even a few individuals at proper intervals during a single season might greatly increase the chances for the successful establishment of the pest.

### Flight of Adults.

The flight of adults is the most important method of local distribution and is also an important element in its association with spread by means of winds and vehicles, railroad trains, and boats.

*The distance to which the insect is capable of flying.*—It would be almost impossible to obtain positive records on the distance the adult citrus white fly is capable of flying. Mr. W. W. Yothers, on April 29, 1908, found on wild persimmon first and second generations of this species of fly at a distance of one-fourth of a mile from the nearest orange grove, which was also the nearest point of the occurrence of a food plant upon which the insect could have passed the winter. The infested persimmons were in pine woods and the insects were in such numbers that it was evident that spread through pine woods might

easily greatly exceed one-fourth of a mile. Mr. W. C. Temple, of Winter Park, Fla., states that he has observed adults migrating into one of his groves on Lake Maitland under circumstances plainly indicating that they had traveled over the water for 1¼ miles. Dr. Berger has recorded an instance which presents strong evidence that adult white flies have heavily infested citrus trees through flights of a mile or more. On the other hand, there are orange groves within three-fourths of a mile of the city limits of Orlando, Fla., and within 2 miles of the courthouse which have only so recently become infested that no blackening of the foliage has taken place, although the citrus white fly has occurred at Orlando for more than 10 years with migrating adults in summer about as abundant as in any town in the State. As regards the capability of flight of the citrus white fly, it may be said to be undoubtedly more than a mile and perhaps several miles when aided by a gentle breeze. Distances of even a mile, however, are not usually attained except under certain circumstances which are largely preventable and which are discussed in the following paragraph.

*Cause of extensive migrations by flight.*—Overpopulation of food plants, usually associated with the emergence of adults in large numbers at seasons when the new and attractive growth is scarce or entirely wanting, is the main cause for migrations from citrus, cape jessamine, and privet. Migrations from China trees and umbrella trees, probably the most potent factors in the spread of the pest, are not due directly to overpopulation, so far as observed, since leaves are never overcrowded in a manner comparable to the overcrowding on citrus leaves. An average of 25 live larvæ or pupæ and pupa cases per square inch of lower leaf surface would represent an unusually heavy infestation of a China or umbrella tree and is rarely exceeded, whereas an average of 50 or 60 per square inch is not unusual for citrus leaves. In the case of China and umbrella trees, migrations are evidently due to lack of attractiveness of the foliage to the adult white flies at the times when the migrations occur. There are comparatively few live larvæ and pupæ on the foliage after the middle of August at Orlando. The greater part of these represent delayed emergence from the second generation of white flies and not the result of eggs deposited by the third brood of adults. This supports direct observations to the effect that the third brood of adults, which is concerned in the most extensive migrations, deposits practically no eggs on the China and umbrella trees.

*China and umbrella trees as a factor in dissemination.*—Umbrella and China trees are extensively grown throughout the Gulf coast citrus-growing regions, and they are almost entirely responsible for the hundreds of millions of adults which in midsummer appear on the wing throughout most of the towns where the citrus white fly

occurs. That these are principally those which have bred upon China and umbrella trees is shown clearly by the fact that at Gainesville, Lake City, Tallahassee, and other points in the northern part of Florida, where other food plants are too few to produce noticeable numbers of migrating adults, the numbers are apparently not less than where both citrus trees and China and umbrella trees are extensively grown, as at Orlando. On this point, Dr. Berger states:[1] "The principal food plants in Gainesville and north Florida are China and umbrella trees, there being only enough citrus, privet, and other evergreen food plants to bring about the restocking of the deciduous trees every spring." These considerations indicate very positively the main source of the enormous number of migrating adult flies on trees in midsummer, sometimes observed between the middle of May and the middle of June. These adults are the second brood of the season and the first to mature on the food plants mentioned. The newer growth of these trees is, as has been shown, very attractive to the adult flies, and if there is an abundance of it comparatively few migrate. The third brood, composed mainly of individuals of the second and third generations, matures over a more extended period, in general covering the months of July and August in different sections of Florida.

Estimates of the number of adult citrus white flies breeding on umbrella trees and on citrus trees as given under the subject of food plants have shown that a single umbrella tree of medium size may produce as many adult white flies by midsummer as could be produced on 7 acres of orange trees. The maturity of so many adults on single trees, and their migration therefrom in search of a more desirable food supply than China and umbrella trees afford in midsummer, cause the rapid spread of the pest throughout the towns, directly by flight of the adults and by mediums hereinafter discussed into the surrounding country and from town to town along railway lines and watercourses.

*Dissemination by flight when citrus trees only are concerned.*—It has been shown under the subject of food plants that the citrus white fly does not ordinarily increase to the point of overcrowding on grapefruit. Migrations of adults in noticeable numbers from solid blocks of these trees probably never occur under ordinary circumstances, and spread through such blocks or groves from the first point of infestation is very slow if no other food plants are concerned. The spread in groves of orange or tangerine trees or of both is more rapid, but not as much so as ordinarily considered. The white fly is rarely observed during its first year's appearance in a citrus grove. Attention is usually first attracted to its presence through the blackening of foliage on one or a few trees. This blackening of foliage in itself

[1] Press Bulletin 108, Florida Agriculture Experimental Station, February 13, 1909.

is almost positive evidence of the presence of the fly in the grove during at least the preceding two years unless the infestation is due to migrations from China or umbrella trees or from overstocked neighboring citrus groves. In such cases infestation may become quite general throughout several acres in one season and extensive blackening of the foliage may result early in the next season, or in about one year after the first introduction. In the case of new infestation in any locality, however, the beginning doubtless is usually the introduction of a few insects by some one of the means hereinafter discussed. In a mixed grove of tangerine and orange the pest is discovered first as a rule on tangerine, and in a grove of seedling trees with a few budded trees intermixed usually the latter are first discovered to be infested. Many citrus growers who have groves, such as those mentioned, and who have watched carefully for the appearance of the pest in their groves, have finally found it well established on a single tangerine or budded orange tree before any evidence of the presence of the insect was observed elsewhere. Through the hindrances to successful establishment and the checks on multiplication, principally those discussed in connection with parthenogenesis and natural mortality, the white fly frequently develops so slowly after its first introduction that it may not increase to the point where it is usually first observed for three or four years. It is a common error to consider that the first discovery of the white fly in a grove is an indication of its very recent introduction. This may or may not be the case. Usually it is not the case. It should be borne in mind in this connection that in the most careful inspection, even by a competent entomologist, the failure to discover a single specimen of the white fly is not positive proof that it is not present. The foregoing generalizations are based upon many observations by the agents of this bureau who have been engaged in these investigations, more particularly the authors of this bulletin and Mr. W. W. Yothers.

The rapidity of spread into a citrus grove from neighboring infested groves is a subject which becomes temporarily important when a nonisolated grove becomes infested for the first time. It is a subject of more far-reaching importance in connection with fumigation, and it is in this connection that the most extensive studies in this line have been made. The result of these studies will be published in a final report on fumigation.

The slowness with which the citrus white fly increases in numbers and spreads from the first point of infestation has been noted by many citrus growers who have been observant enough to discover the white fly soon after its introduction into their groves. When the rate of spread of the white fly through the grove is affected by the presence of migrating adults from China or umbrella trees, the

difficulties in effectively utilizing artificial checks, spraying and fumigation, are greatly increased. As the infested area in a newly infested grove or locality becomes larger the rate of spread by flight increases, aided by secondary centers of infestation which become established by various means.

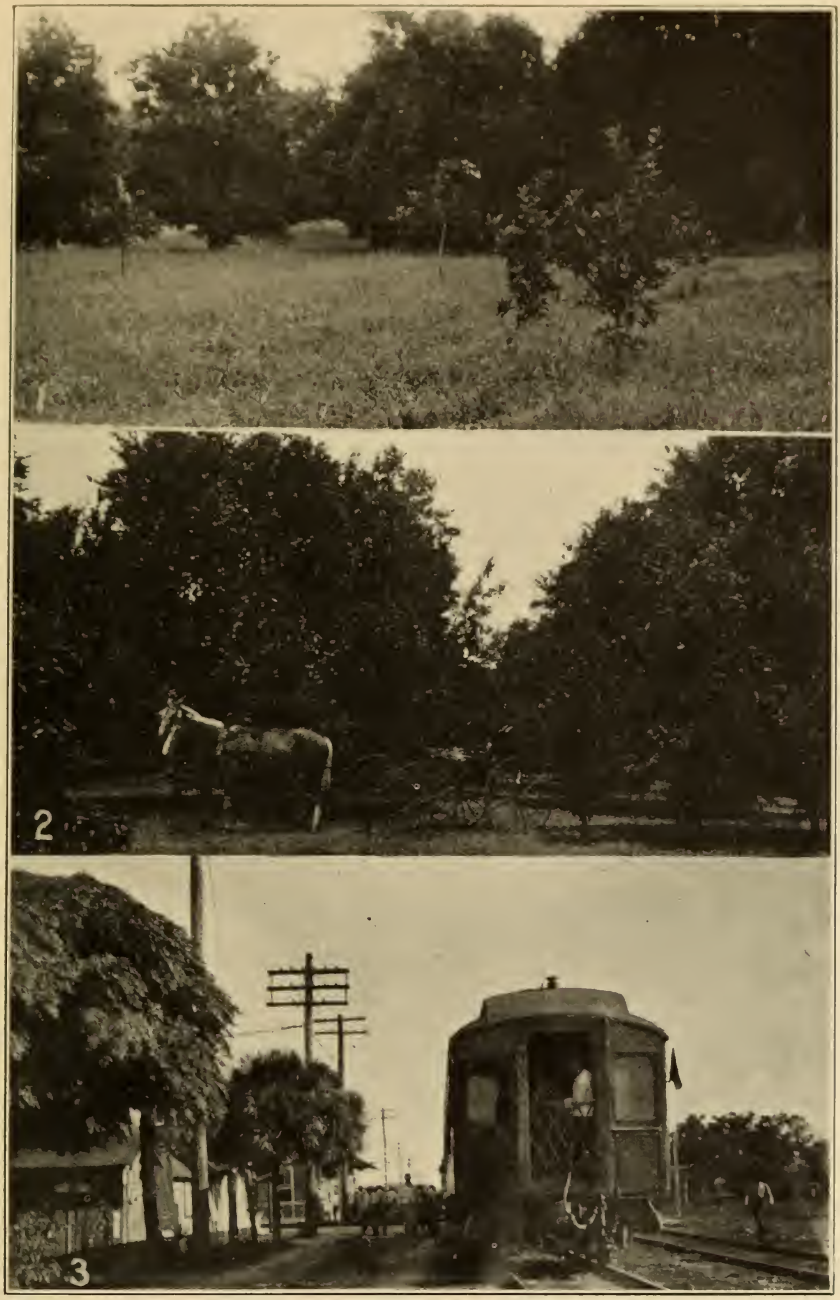
### Winds.

Light winds are an important adjunct to flight in the local distribution of adult white flies, but strong winds are ordinarily of slight consequence. The effect of light winds is shown by the influence of almost imperceptible movements of the air on the direction of migrations. This is especially noticeable in the vicinity of China and umbrella trees during a season when adults are emerging in abundance. The principal effect of the movement of the air under such conditions is not in carrying the insects, but in causing the flight energy of the insect to be expended in one general direction rather than to be wasted in zigzag lines with comparatively little real progression. Other conditions being equal, the adult white flies migrate in greatest abundance when the atmosphere is calmest, and conversely show the least tendency to migrate in strong winds. It is possible that isolated infestations may sometimes result from spread of adults by strong winds, but it is seldom that there is not a more plausible explanation obtainable. With the white fly present in abundance for many years in Orlando, Fla., and other towns and cities in important orange-growing sections of Florida, the fact that there are still many noninfested citrus groves within a radius of 5 miles of nearly all such centers of infestation is in itself an indication of the minor influence of winds in this connection. Strong breezes or winds exert some check on the spread of adults by causing them to cling tenaciously to their support, as pointed out by Prof. H. A. Gossard.[1]

### Vehicles, railroad trains, and boats.

In towns in Florida where the citrus white fly occurs and China trees and umbrella trees are abundant it is a matter of common observation that during the periods of migration large numbers of adults alight upon automobiles, carriages, wagons, and railroad coaches. The authors have seen covered carriages with more than 100 adults resting on the inside of the top and sides. In driving through a heavily infested citrus grove in late afternoon at certain seasons, hundreds of adults may be observed on the carriage (Pl. VI, fig. 2). Newly infested groves show the first infestation so frequently on trees close to a driveway or road that conveyance of the citrus white fly by means of carriages, wagons, and automobiles must be considered one of the most important methods of spread from town to surrounding

[1] Bulletin 67, Florida Agricultural Experiment Station, p. 13.




DISSEMINATION OF WHITE FLIES.

Fig. 1.—Nursery citrus trees infested with white flies set out in an isolated noninfested grove without having leaves removed. Fig. 2.—Buggy in an orange grove; buggy top full of adult white flies ready to be carried to other groves. Fig. 3.—Train at station; adult citrus white flies swarming from near-by umbrella China trees into coaches ready to be carried for miles down the Florida east coast. (Original.)

country or from grove to grove. At Orlando, in July, 1906, adult citrus white flies were observed late in the afternoon alighting on the sides of coaches and flying into the windows and doors of coaches of a passenger train standing at a railroad station (Pl. VI, fig. 3). Hundreds of adults were carried west toward Wildwood through points which, so far as known, were not infested at the time. The presence of China, umbrella, or citrus trees near railroad stations increases the chances for successful introduction by railroad trains. In this connection the recent action of the Atlantic Coast Line Railroad and Seaboard Air Line Railway in destroying such trees along their right of way is to be commended. A map of Florida showing the distribution of the citrus white fly plainly indicates the relation between the railroads and the main lines of dissemination. This is shown in an incomplete way by figure 2, in which are given the points infested by the citrus white fly in Florida according to the records made in connection with the present investigation and such other records as are undoubtedly correct or which have been verified. The infestation at Arcadia, Fla., first discovered in January, 1907, but which probably resulted from an introduction of citrus white flies in 1905, was with little doubt due to the introduction of adult flies by means of railroad trains. An examination of the situation in February, 1907, by the senior author showed the center of infestation to be located near railroad stations, and careful inquiry concerning other possible sources showed that railroad trains were the most likely means of introduction. North of Arcadia no nearer infested point was known than Bartow and toward the south no nearer infested point than Fort Myers. The distance in each case was about 40 miles. So far as known there were at that time no intermediate points infested between Arcadia and the two points mentioned. Here again the factors unfavorable to the successful establishment of the pest in a previously uninfested locality play an important rôle, as shown by the fact that even at the present writing the citrus white fly is not generally distributed between Bartow and Fort Myers. As we have no record and have heard no report of the occurrence of the fly at any other point than Arcadia, it is unlikely that other infested points exist.

Steamboats are used quite extensively on the rivers and along the coast of Florida in transporting citrus fruits and have in a degree a similar status to railroad trains in transporting the citrus white fly.

### Citrus Nursery Stock and Ornamental Plants.

The carriage of the citrus white fly in its egg, larval, and pupal stages by means of citrus nursery stock (Pl. VI, fig. 1) and ornamental plants has always been an important factor in the spread of the

insect. The citrus white fly was without doubt introduced into the United States and distributed to the most important centers of infestation by this means. In Florida the white fly was probably introduced first on citrus nursery stock into some citrus grove on the St. Johns River in St. Johns County, and later by the same means into Manatee and Fort Myers. Gainesville, Ocala, Orlando, and Bartow were probably among the points to which the white fly was introduced on nursery stock. The distribution of the citrus white fly along the Gulf coast citrus-growing regions west of Florida has been largely due to shipments of infested citrus nursery stock, umbrella trees, privets, and cape jessamines. Of all methods of spread which are operative over greater distances than the flight of adults, introductions of live immature stages on trees or shrubs for transplanting purposes are by far the most certain to result in the successful establishment of the species. Fortunately it is practicable to prevent spread by this method by defoliating the trees as they leave the nursery. Much has been accomplished in the past by individual citrus growers, but more attention should be given to this matter in communities not now infested by both of the white flies treated in this bulletin.

### Accidental Spread by Man.

*Carriage of the adult white flies on human beings.*—Man is doubtless responsible to a limited extent for the spread of adult white flies. During migrating periods, when in heavily infested orange groves or in towns where there are infested China and umbrella trees, adults are frequently observed on the clothing. Prof. H. A. Gossard states that he has carried adult white flies for nearly half a mile on his clothing after standing beneath a heavily infested tree.

*Introduction in pickers' outfits.*—In some instances the citrus white fly is believed to have been introduced into previously uninfested localities by orange pickers. In this case the principal danger lies in introducing live pupæ on citrus leaves accidentally brought in with picking sacks and field boxes. The authors consider that there is practically no danger of the carriage of adults of the citrus white fly by pickers' outfits between December 1 and March 1. The few adults present in citrus groves during this period would rarely result in their transference to uninfested groves by such means, and the unfavorable factors heretofore discussed would almost certainly prevent the successful establishment of the pest. It would be almost impossible to conceive of any likely method by which a successful introduction of the citrus white fly into a noninfested grove could be accomplished by the carrying of leaves infested by eggs or larvæ. Leaves infested with live pupæ, however, particularly about the time of the beginning of emergence of the first spring brood,

might readily produce a sufficient number of adults to successfully establish the pest. Such leaves, after introduction, would need to have a favored location, for exposure to much sunlight or to too much moisture would soon destroy the insects.

*Introduction on leaves infested with parasitic fungi.*—The matter of spread of the white fly in connection with the attempt to introduce parasitic fungi is a subject of considerable importance. The danger here is due to the failure to recognize the distinction between the citrus white fly (*Aleyrodes citri*) and the cloudy-winged white fly (*Aleyrodes nubifera*). The owner of a grove infested by the latter species only, would provide a very favorable opportunity for the introduction of the first and most destructive species if in introducing parasitic fungi he should obtain his supply of leaves from certain sections of Florida. The spread of the cloudy-winged white fly has been encouraged in a similar manner. The tree-planting method of introducing the fungi, especially the brown fungus, is the most dangerous practice in this connection. Of somewhat less danger in the individual cases, but of far greater danger on account of the more frequent opportunities presented, is the introduction of fungus-infected leaves for pinning or for spraying the spores. The pinning of leaves as a means of introducing the parasitic fungi has little more to recommend it than the tree-planting method, but it has without doubt been the means of introducing the citrus white fly on many occasions. Leaves introduced for the spore-spraying method of spreading the fungus parasites are an element of much danger under certain conditions. Some sections of Florida in which only the cloudy-winged white fly occurs are in more danger of having the citrus white fly introduced by some uninformed person in this way than they are of its introduction in any other manner. Specific examples might be cited where the introduction of either *A. citri* or *A. nubifera* was with little doubt due to introducing fungus-infected leaves or trees, but the danger is too obvious to require further discussion in this place.

## LIFE HISTORY AND HABITS.

### Summary.

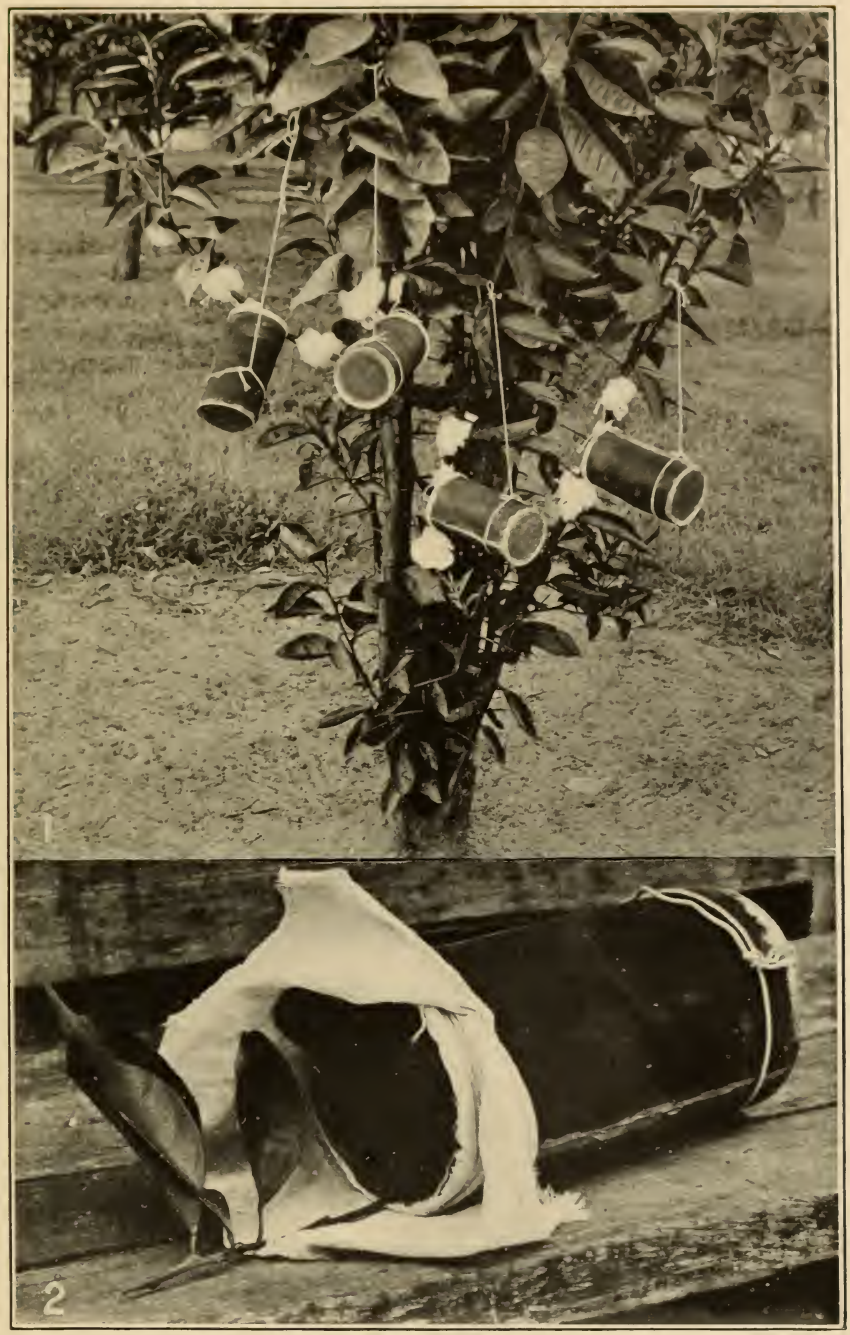
The eggs of the citrus white fly (fig. 3) are laid scatteringly, with few exceptions, on the underside of the leaves of the various food plants, and hatch in from 8 to 24 days, according to the season. During ordinary summer weather from 75 to 100 per cent hatch on the tenth to twelfth day. Infertile eggs hatch as readily as fertile eggs and produce adults of the male sex only. After hatching, the young larva (figs. 4–6) actively crawls about for several hours, when it ceases to crawl, settles upon the underside of the leaf, and begins to feed by sucking the plant juices. It molts three times before

becoming a pupa. After the first molt (see fig. 7) the legs become vestigial; hence thereafter it is impossible for it to materially change its location upon the leaf. Larval life averages in length from 23 to 30 days. The pupa (fig. 9) closely resembles the grown larva (fig. 8) and requires from 13 to 304 days for development. The adult fly (fig. 10) has an average life of about 10 days, although several females have been known to live 27 days. Females may begin depositing eggs as soon as 6 hours after emergence and continue ovipositing throughout life. The maximum egg-laying capacity is about 250 eggs, although 150 more nearly represents the number laid under grove conditions. Unfertilized females deposit as many eggs as fertile females.

The entire life cycle from egg to adult requires from 41 to 333 days; the variation in the number of days required from eggs laid on the same leaf on the same day is very remarkable. During the course of the year the fly may pass through a minimum of two generations and a maximum of six generations. The generation started by the few adults that emerge during the winter is entirely dependent upon weather conditions and may or may not occur. Each generation except those started after the middle of August is more or less distinctly two-brooded.

### Methods of Study.

As it is impossible to rear citrus white flies through their entire life cycle on detached leaves, a gauze-wire cage was devised by the senior author which has proved of great value and convenience in carrying on life-history studies under conditions as nearly normal as it is possible to get them. This cage (Pl. VII), which is cylindrical in shape and open at one end, may be made any size, but one 6½ inches long by 3½ inches in diameter has proved most convenient. It can easily be made by fashioning two rings of heavy wire to which is soldered the wire gauze, as shown in the illustration. To the open end is attached a piece of closely woven cheesecloth long enough to extend about 4 inches beyond the cage. After the leaf, or leaves, to be caged have been cleaned of all stages of the white fly by means of a hand lens and cloth, the cage is slipped over the foliage. The adult flies are then introduced, if desired, and the cloth attached to the cage wrapped around the stem of the shoot or petiole of the leaf, as the case may be, in such a manner that the flies can not escape nor the ants and other predaceous insects enter. To keep the entire weight of the cage from falling on the petiole of the leaf or its short stem, and to regulate the position of the leaf within the cage, a cord is tied around the outer end of the cage and attached by the loose end to a convenient branch.



CAGES FOR REARING WHITE FLIES.

Fig. 1.—Rearing cages in position on orange trees. Fig. 2.—Enlarged rearing cage. (Original.)

A very satisfactory method of definitely marking larvæ in order that no mistake may be made in identifying field notes with the individual larvæ to which they refer, is to scratch lightly on the epidermis of the leaf, with a thorn or pin, a bracket or other mark and outside this a number that shall correspond with that used in the note book. In marking larvæ care should be taken in scratching the leaf to allow for the future growth of the insect and not to injure the epidermis of the leaf too severely. In this manner a large number of larvæ were marked as soon as they settled and their growth noted by daily observations.

In determining the sums of effective temperature, 43° F. has been taken as a basis in accordance with Dr. Merriam's general law although this has led to certain inaccuracies of which the authors are aware. The determination of the effective temperature in the case of the white fly would require a special study which it has been impracticable to undertake.

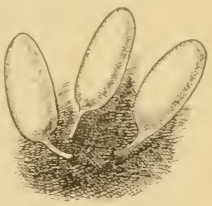


FIG. 3.—The citrus white fly (*Aleyrodes citri*): Eggs. Greatly enlarged. (Original.)

## THE EGG.

### DESCRIPTION.

The eggs of the citrus white fly (fig. 3) are so small that they appear to the unaided eye as fine particles of whitish dust on the under surface of the leaves. Their minute size is emphasized by the fact that 118 placed end to end would measure but an inch, while about 35,164 could be placed side by side in one square inch. Under the magnifying lens they appear as smooth, polished, greenish-yellow objects shaped much like a kernel of wheat. Following is a more minute description:

Length, 0.2–0.23 mm.; width, 0.08–0.09 mm. Surface highly polished, without sculpturing, color pale yellow with faint greenish tinge when first deposited, paler than the under surface of the leaf. Egg elongate, subellipsoid, slightly wider beyond the middle or at about the point where the eyes of the embryo subsequently appear; borne at end of a comparatively slender brownish petiole or footstalk, slightly shorter than the width of the egg, and somewhat knobbed at base.

As the embroyo approaches maturity its purple eyes may be seen showing distinctly through the egg membranes at a point beyond the middle of the egg. At about this time, also, the hitherto uniformly colored egg contents become orange or golden at the proximal end and whitish translucent on the distal three-fourths. The egg surface sometimes assumes a white pruinose appearance, due to the presence of wax rubbed from the bodies of the adults while crawling over the eggs. Eggs deposited on leaves from which the adults have been excluded after egg deposition do not show this pruinose condition.

Eggs in which the embryonic development is normal do not turn dark in color, but those killed through attack by thrips or by other agency frequently become bronze colored, thus resembling the eggs of *A. nubifera* from which the waxy sculpturings have been rubbed.

### DURATION OF EGG STAGE.

That no doubt might arise concerning the exact age of the eggs used in obtaining the data incorporated into Table VIII, suitable leaves were selected from which all eggs previously deposited were carefully removed by the aid of the hand lens and a cloth. Similar attention was given the leaf petiole and the stalk, and wads of cotton were tied about the latter both above and below the leaf to prevent crawling young from reaching the leaf along the petiole (Pl. VII, fig. 1). These preliminary steps completed, a rearing cage containing adult white flies was placed over the leaf and allowed to remain the length of time desired, usually from 1 to 24 hours, with preference shown the latter number. The cage was then removed and an empty one put in its place. By this method all doubt was removed as to the period of time over which deposition took place. As there is scarcely a leaf in a grove infested with the citrus white fly that does not bear from a few to many eggs, this becomes an important point and failure in its recognition has led in the past to statements greatly underestimating the minimum duration of the egg stage during the warmer months.

TABLE VIII.—*Duration of egg stage of the citrus white fly.*

| Record number. | Date deposited. | Eggs under observation. | First egg hatched. | Last egg hatched. | Least number of days. | Largest number of days. | Daily rate of hatching in percentages with degrees of accumulative effective temperatures. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 8 days. | °F. | 9 days. | °F. | 10 days. | °F. | 11 days. | °F. | 12 days. | °F. | 13 days. | °F. | 14 days. | °F. |
| | 1909 | | 1909 | 1909 | | | | | | | | | | | | | | | | |
| 1 | Feb. 23 | 163 | Mar. 13 | ..... | 18 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... |
| 2 | Mar. 3 | 305 | Mar. 17 | Mar. 24 | 14 | 21 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... |
| 3 | Apr. 20 | 452 | May 1 | May 6 | 11 | 16 | 0 | ..... | 0 | ..... | 0 | ..... | .5 | 401 | 0 | 422 | 96.2 | 442 | .5 | 470 |
| 4 | June 16 | 360 | June 26 | June 30 | 11 | 15 | 0 | 0 | 0 | ..... | 0 | ..... | 5.4 | 383 | 60.6 | 424 | 14.7 | 462 | 14.8 | 486 |
| | 1907 | | 1907 | 1907 | | | | | | | | | | | | | | | | |
| 5 | July 17 | 927 | July 26 | Aug. 5 | 9 | 19 | 0 | ..... | 0.1 | 371 | 24.3 | 409 | 75.5 | 449 | 0 | ..... | 0 | ..... | 0 | ..... |
| 6 | July 19 | 1,225 | July 30 | July 31 | 11 | 12 | 0 | ..... | 0 | ..... | 0 | ..... | 49. | 454 | 51.0 | 497 | 0 | ..... | 0 | ..... |
| 7 | Aug. 1 | 448 | Aug. 11 | ..... | 10 | ..... | 0 | ..... | 0 | ..... | 8. | 393 | 90. | 429 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 1908 | | 1908 | 1908 | | | | | | | | | | | | | | | | |
| 8 | Sep. 18–21 | 260 | Sept. 26 | Oct. 2 | 8 | 11–15 | 1.2 | 282 | 1.9 | 318 | 1.9 | 355 | 15. | 389 | 45.4 | 424 | 30.4 | 490 | 4.2 | 493 |
| 9 | Sept. 21 | 314 | Oct. 2 | Oct. 8 | 11 | 17 | 0 | ..... | 0 | ..... | 0 | ..... | 14.0 | 385 | 65.9 | 415 | 6.1 | 445 | 9.5 | 477 |

| Record number. | Daily rate of hatching in percentages with degrees of accumulative effective temperatures. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 days. | °F. | 16 days. | °F. | 17 days. | °F. | 18 days. | °F. | 19 days. | °F. | 20 days. | °F. | 21 days. | °F. | 22 days. | °F. | 23 days. | °F. | 24 days. | °F. |
| 1 | 0 | ..... | 0 | ..... | 0 | ..... | 3.0 | 583 | 1.5 | 626 | [1]0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 2 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | .3 | 518 | 0.7 | 544 | ..... | 575 | [2]93.4 | 611 | ..... | 655 | [2]5.6 | 695 |
| 3 | 1.5 | 500 | 1.3 | 531 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 4 | 4.5 | 532 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 5 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | .1 | 770 | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 6 | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 7 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 8 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 9 | 2.5 | 507 | 1.0 | 538 | 1.0 | 570 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

[1] The thrips *Aleurodothrips fasciapennis* Franklin is responsible for death of 95.5 per cent of the eggs.

[2] Records include eggs hatching on previous day.

The conclusions presented herewith are drawn from the data presented in Table VIII, based upon daily observations of over 5,000 eggs deposited at intervals from February to October. From these and other data not included, it can be stated that the eggs hatch during a period of from 8 to 24 days after deposition, according to the season of the year. While there are no data regarding the length of the incubation period for eggs deposited by the few female flies occasionally seen during the winter months, as noted under seasonal history, it is probable that hatching extends over even a greater number of days during the winter season. The deposition of such eggs is, however, a comparatively rare occurrence and will receive no further mention here. In no instance have eggs been seen to hatch before the eighth day from deposition, even during the months July and August, 1907, when the average mean temperatures were slightly above normal, while under the most favorable summer weather conditions from 75 to 100 per cent of the eggs hatch during the period from the tenth day to the twelfth day from deposition.

In general, the warmer the season the shorter and more nearly uniform is the period of egg development or incubation. During the months of July and August, when the normal monthly temperatures at Orlando range from about 72° F. as the mean of the minimums to about 93° F. as the mean of the maximum records, practically all the eggs hatch from the tenth day to the twelfth day. Even at this most favorable season, in one instance hatching was delayed for 19 days. During the somewhat cooler weather of late September and early October and the decidedly cooler months of February, March, and April, hatching is more or less delayed according to the prevailing temperature and is scattered over a larger number of days. This same result is brought about, only in a less degree, by a cool period occurring in an otherwise warm season, as shown under record 4 (Table VIII).

Reference to the daily rate of hatching in Table VIII, and to the accompanying degrees of accumulated effective temperatures, shows that regardless of the time of year deposited and the number of days required for incubation, over 90 per cent of the eggs, on an average, hatch between the accumulation of from 375° to 475° of effective temperature.

Exception to this statement must be taken in records 1 and 2 (Table VIII). The number of degrees of effective temperature required seems to be greater at this season, although this might not prove to be the case if, as is probable, an error has arisen from using 43° F. as the basis for calculating the effective temperature.

Reference to the two preceding tables shows that considerable variation exists in the length of the egg stage among eggs deposited on the same day, or even within the same hour, and subsequently

subjected to identical conditions of heat and moisture. Even when hatching was most concentrated during the heat of summer and 99.8 per cent of the eggs hatched on the tenth and eleventh days from date of deposition, hatching extended over a period of from 9 to 19 days. Hatching over a period of from 6 to 7 days after the first crawling young appears is an ordinary occurrence during the cooler portions of the season of activity. In this respect, white-fly eggs are markedly different from the eggs of most other insects deposited in batches which usually hatch within one or, at the most, a few hours of each other.

PARTHENOGENESIS.

The existence of parthenogenesis among aleyrodids was first recognized by the senior author [1] in connection with his investigations of the greenhouse white fly (*A. vaporariorum*). His prediction at that time that this method of reproduction would ultimately be proved to occur among many if not all the species of Aleyrodes has been strengthened by the results of the present investigations. While there are no definite data to the effect that parthenogenetic eggs are deposited under natural conditions, there is practically no doubt that such deposition does occur, especially by females not yet mated or by females appearing at unseasonable times or when males are decidedly in the minority. Scattered females emerging during the winter, or resulting from the comparatively few pupæ surviving fumigation, either never have the opportunity to mate or deposit many of their eggs before such opportunity presents itself.

That virgin females of *A. citri*, emerging from pupæ kept separately in vials, and later confined in rearing cages under normal grove conditions, except for the exclusion of males, will readily deposit the normal number of eggs, and that these eggs will develop normally and will produce adults of the male sex, has been thoroughly demonstrated. Of the five separate cage experiments started with parthenogenetic eggs, all of 111 adults emerging in four of the cages were males, while of 208 more adults emerging from the fifth cage, all but 4 individuals were males; the 4 females emerging under such conditions as to lead to the supposition that they came from fertile eggs overlooked in preparing the leaf for the experiment.

HATCHING.

In hatching, the egg membranes rupture at the end opposite the pedicel, and then split down each side sufficiently to permit the young larva to crawl out. The glistening eggshell, somewhat resembling in appearance a bivalve shell, eventually becomes shriveled and loses its original form.

[1] Notes on Some Aleyrodes from Massachusetts, with Descriptions of New Species. Psyche, April, 1903, p. 81. Technical Bulletin No. 1, Mass. Agr. Exp. Sta., pp. 31–33.

*Proportion of eggs that hatch.*—Observations covering many thousands of eggs, both in the cage experiments and in the grove, have demonstrated that the number of eggs that fail to hatch is too insignificant and has too little practical bearing to warrant the collection of data on this point. It is safe to say that considerably less than 1 per cent do not hatch. In fact, it seems evident that no egg would fail to hatch except owing to the dropping of the leaf or unless subjected to attack from without. In many instances failure to hatch can be directly traced to attack by several species of insects and a fungous parasite.

*Effect of drying of leaves on hatching.*—In 10 instances leaves bearing many thousand eggs were so placed that the eggs were exposed to direct sunlight or to partial shade, and although frequent observations were made none of the eggs were known to hatch. In general the drying of leaves to which eggs are attached prevents hatching of all except those eggs containing nearly mature embryos. This feature is probably common to all aleyrodids, since the senior author has noted a similar occurrence in the case of the greenhouse white fly (*A. vaporariorum*).

## The Larval and Pupal Stages.

### DESCRIPTION OF STAGES.

#### THE LARVA.

The larvæ[1] are thin, translucent, elliptical, scalelike objects, found usually on the underside of the leaves, though more rarely upon the upper surface. When normally attached to the leaf they are so nearly transparent as to be seen with difficulty. They readily become visible, however, by either bending or rubbing the fingers along the opposite side of the leaf, thus loosening them and allowing the air to get beneath them. They then appear whitish (Pl. X, fig. 2). So very inconspicuous are the live larvæ and their attack so unaccompanied by any visible effects on the leaves, aside from the blackening of the foliage, that their presence is very frequently overlooked by the casual observer. A detailed description follows:

*First instar larva* (figs. 4–6). Length, 0.3 to 0.37 mm.; width, 0.182 to 0.22 mm. Body flat, scalelike, somewhat swollen ventrally, especially in the cephalothoracic region; margin entire, with 30 small tubercles, each bearing a horizontally directed spine of which 6 cephalic and 4 anal are proportionately longer. Spines of second pair, counting from anterior end of body, arising from tubercles not on, but slightly posterior to, margin on ventral surface. Relative lengths of the 15 pairs of spines as follows:

| Pair | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spaces | 11 | 9.8 | 11 | 6.5 | 5.4 | 5.5 | 6 | 4 | 4 | 4 | 18 | 5.4 | 18.5 |

[1] The larvæ and pupæ are frequently called by many growers the "egg" of the white fly. This misapplication of terms should be discouraged as it leads to undesirable confusion when referring to the various stages through which the white fly passes during its growth from egg to adult.

No marginal wax fringe appears before or after crawling young settles. Cephalothoracic and thoracic articulations invisible; 8 or possibly 9 abdominal segments are seen with little difficulty. Segments at posterior end of body modified by vasiform orifice. Latter nearly semicircular in outline, somewhat longer than wide, bordered laterally by chitinous thickenings which do not meet posteriorly; operculum semicircular, nearly equaling in size the vasiform orifice itself, covering the ligula and bearing on its median posterior margin what appear to be two pairs of small spines, the penultimate pair of which is about twice as long as the ultimate. Ligula darker in color and broadly crescentic in shape. On either side of, and slightly anterior to, the vasiform orifice is a short backwardly directed spine arising from a small tubercle. The two pairs of rounded, simple, reddish-brown eyes, less than 0.01 mm. in diameter and 0.096 mm. apart—a dorsal pair and a ventral pair—are situated mesad and slightly anterior to the fifth pair of marginal spines, the dorsal pair being nearer the margin and slightly anterior to the ventral pair.

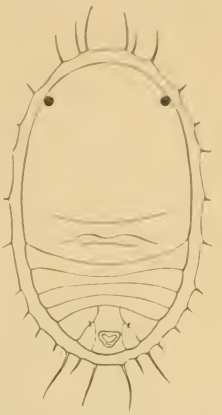


FIG. 4.—The citrus white fly: Crawling young; first instar, dorsal view. Greatly enlarged. (Original.)

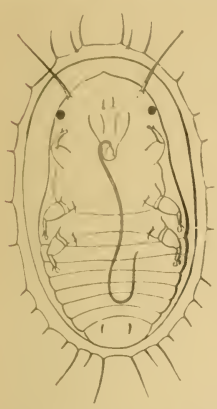


FIG. 5.—The citrus white fly: Crawling young; first instar, ventral view. Greatly enlarged. (Original.)

Antennæ, legs, and mouth-parts on the venter. Antennæ anterior and mesad to the anterior pair of legs, 0.1 mm. long, very slender; apparently 4-segmented, articulations between the segments seen with difficulty and frequently that between the third and fourth entirely wanting, while in a few specimens the second segment appears to be divided into two parts: Segment 1 short, stout, fleshy; segment 2 one-half as wide and twice as long as segment 1; segment 3 narrower than segment 2 and about four times as long; segment 4 very slender, less than one-half as long as segment 3, and bearing on its proximal posterior side a minute spine, and distally a long spine. Legs short, moderately stout, where extended about one-third the width of the body; coxæ very short and stout, the two posterior pairs on the posterior inner side with a moderately stout spine about equal in length to the diameter of the coxæ and directed backward and inward; trochanters distinguished with difficulty, about one-third as long as wide and collar-shaped; femora more elongate, slightly tapering distally, about four times as long as trochanters; tibiæ much narrower, somewhat longer than the femora, with numerous short bristles, two on the outer proximal portion longer and more easily seen, on the outer distal portion with a long bristle forwardly directed and curving inward toward the tip of the tarsi; tarsi short, ending distally in an enlarged disk-like process.

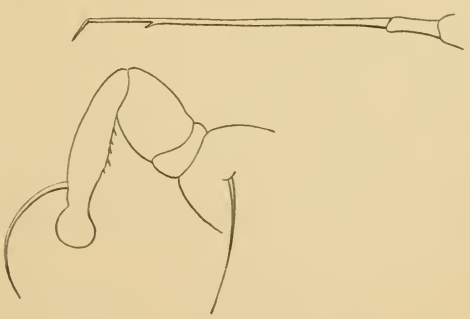


FIG. 6.—The citrus white fly: Antennæ and left hind leg, first instar. Highly magnified. (Original.)

Midway between the anterior pairs of legs in the middle of the body is the fleshy mouth papilla from which arise the mouth setæ, at first when bent backward reaching only to slightly beyond the posterior coxæ, but later becoming more elongate. Anterior to the mouth papilla is the semiovate prostomal plate, extending anteriorly as far as a line connecting the antennæ, and divided longitudinally by two curved sutures into one elongate median and two shorter lateral pieces. At the anterior end of the prostomal plate is a pair of small papillæ, each papilla bearing a small forwardly directed spine.

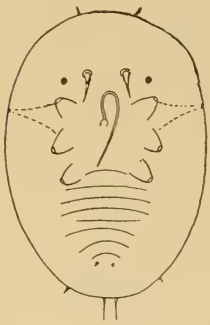


FIG. 7.—The citrus white fly: Second larval instar, ventral view. Greatly enlarged. (Original.)

On the venter beneath and to the side of the vasiform orifice is a pair of spines arising from small tubercles, normally directed backward and outward, equal in length to the distal tibial spine.

*Second instar larva* (fig. 7).—Length, 0.37 to 0.43 mm.; width, 0.24 to 0.29 mm. Broadly ovate, dorsum densely rugose, all marginal tubercles and spines wanting except 2 cephalic and 4 anal, the three pairs, counting from the cephalic region, giving the relative lengths: $\frac{1}{9.5}$, $\frac{2}{4.5}$, $\frac{3}{10.5}$. Eyes smaller and less regular in outline than in the first instar, but distinctly evident. Antennæ greatly reduced, unsegmented, directed backward and slightly outward, tapering, reaching nearly to base of first pair of legs; on inside near base with a distinct spinelike projection, and on basal portion with numerous roughenings; legs almost rudimentary, reduced to short, stout, fleshy processes without distinct segments, composed of a very stout, tapering basal portion, and a comparatively small, rounded, thick terminal disc; the second and third pairs of legs on the inner side at the base with a minute spine. Mouth parts as in previous stage; prostomal plate anteriorly indistinct and its pair of spines wanting. Spines on either side of vasiform orifice, both on dorsum and venter, as in first instar. A marginal pore, on either side of body opposite base of first pair of legs, and formed by an upward fold of the integument, becomes very evident in this instar.

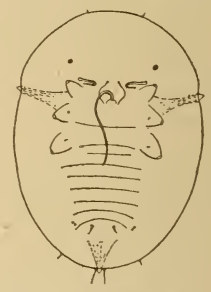


FIG. 8.—The citrus white fly: Third larval instar, ventral view. Greatly enlarged. (Original.)

*Third instar larva* (fig. 8).—Length, 0.62 to 0.78 mm.; width, 0.43 to 0.58 mm. Very similar to second instar but larger; the most striking difference presented by the antennæ, which have migrated backward so as to arise from a tubercle slightly anterior to base of first pair of legs. Antennæ immovable, directed mesad for about two-thirds of their length, and then suddenly doubled backward so that the distal third lies in the same plane as the basal portion. Legs smaller in proportion than in second instar and prostomal plate less developed, but the marginal pores and anal cleft more fully developed. A waxen rod is seen often protruding from the marginal pores. Relative lengths of the marginal spines: $\frac{1}{3-4}$, $\frac{2}{2.5}$, $\frac{3}{4.5}$.

THE PUPA.

The introductory remarks regarding the general appearance of the larva apply with equal force to the young pupa (fig. 9, *a*, *b*, and *c*), with the exception that the pupa is larger, being nearly one-sixteenth of an inch long, is more easily seen, and on either side of the thoracic region 3 distinct curved lines representing the outlines of the legs

are very distinct. As the pupa becomes older it becomes thicker, more rounded and opaque, and the outlines of the legs are obscured by the contents of the body. At the approach of maturity a bright red or orange spot develops on the back, and from three to eight days before emergence the eyes of the adult become visible. A detailed description is as follows:

Length, 1.10 mm to 1.40 mm; width, 0.60 mm to 1.0 mm. Body broadly elliptical, thin, not raised from leaf on vertical wax fringe, color pale yellowish-green, becoming more yellowish and thicker on approaching maturity; thoracic lobes, representing outlines of the three pairs of legs, and a line extending from between first two pairs of legs and from the vasiform orifice to edge of body distinctly more yellowish, as are also the lines representing the union of the body segments although these last are prominent. As body thickens thoracic lobes become less distinct due to body contents, a bright orange or red medio-dorsal spot develops at anterior end of abdomen, and later, a few days before emergence, the purple eyes of adult become very distinct, as also do the white developing wing pads; rim of vasiform orifice brown or yellowish. All marginal bristles lost except one anterior and one posterior pair of minute bristles. A low medio-dorsal ridge or carina and corresponding depressions on each side extend from the head to the anal ring, traversed by short transverse ridges on the thorax and abdomen, terminating in a low subdorsal ridge hardly perceptible; from these last numerous very fine granulated striæ radiate all around the body to the lateral margin. A short transverse ridge appears near posterior margin of head with a curved impressed line in front. A minute brown tubercle at the anterior end of the subdorsal carina is sometimes to be seen. From a pore at the edge of the body, between head and thorax and top of anal slit, issues a very fine, glistening-white, curled thread of waxen secretion. These so-called "pores" in margin of the cephalo-thoracic region are formed by a slight upfolding of the body which extends from margin to cephalo-thoracic spiracle and forms an outlet for secretions from same. Location of spiracles and respiratory system as already described for aleyrodids. Legs and antennæ easily seen with high-power lens. Antennæ located as shown in fig. 9, partially concealing front pair of legs, apparently 3-segmented but division into segments not distinct; last segment as long as other two combined, with quite a number of irregular annulations; tip provided with a stout spine. Legs short, very stout, especially the two posterior pairs; front legs projected forward; all without distinct segmentation; tarsus very short, stout, and rounded. Vasiform orifice nearly semicircular (for details and shape see fig. 9, *b*).

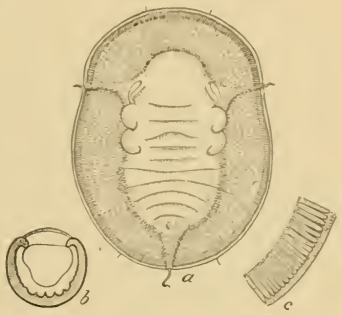



FIG. 9.—The citrus white fly: *a*, ventral aspect of pupa; *b*, vasiform orifice of same; *c*, margin of body of same. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

*Pupa case.*—White, firm, retaining definite shape, and remains firmly attached to leaf unless forcibly detached. (See Pl. VIII, fig. 1.)

## DURATION OF STAGES

### LARVAL INSTARS.

Data upon the duration of the larval instars have been secured by daily observations of over 300 specimens marked as soon as the young larvæ had settled, supplemented by frequent counts of several thousand specimens in various life-history cages.

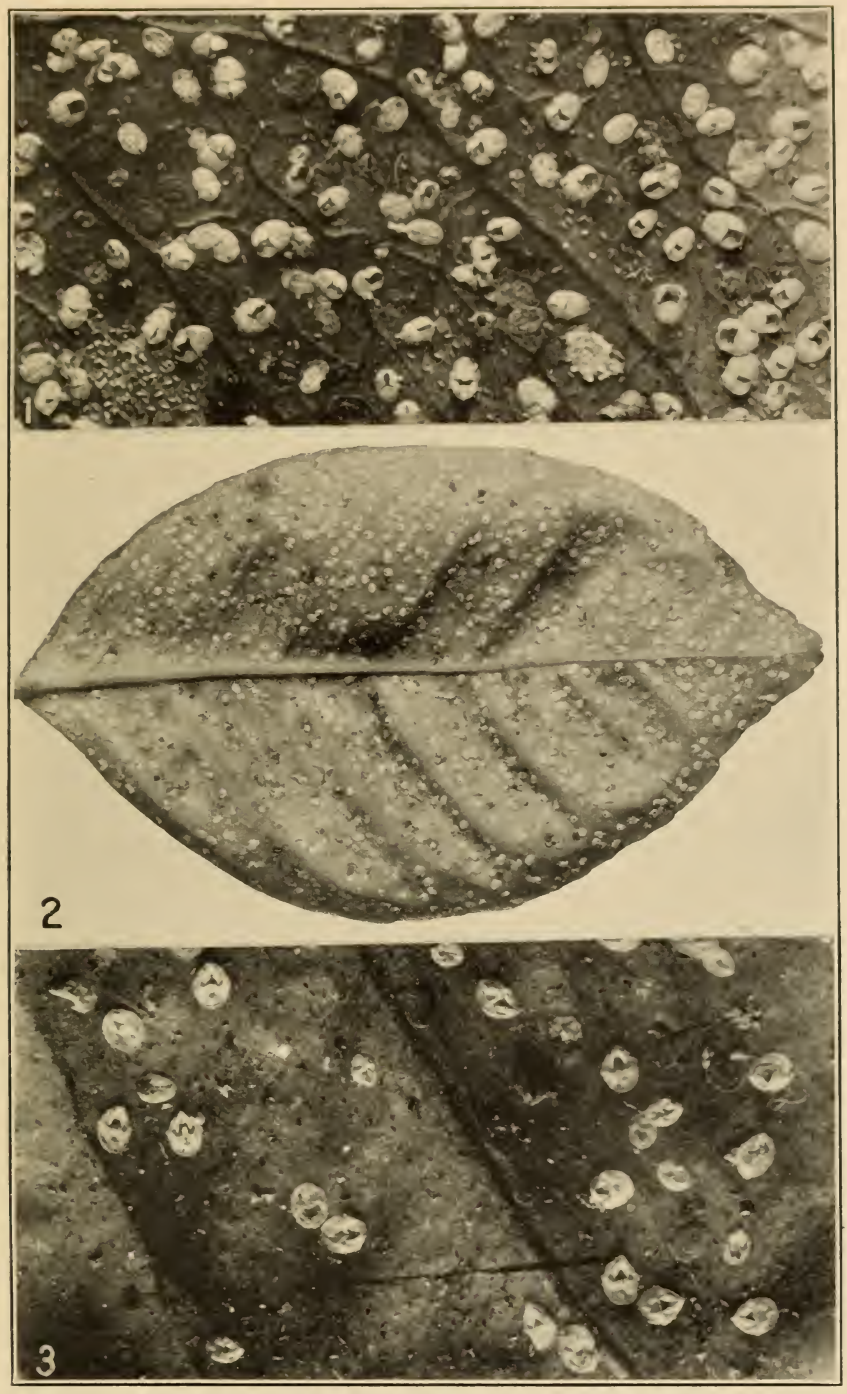
From these records those included in Table IX have been chosen as representative. A study of these will give a very accurate knowledge of this subject, and will impress upon one the considerable variation in the duration of the several instars of larvæ hatching at the same time, feeding upon the same leaf, and consequently subject to the same weather conditions. The data also emphasize the retarding effect of cool spring and fall weather upon the length of larval life, although this has not been found to be as great as many have thought. The period of larval growth ranges from an average of 23 days during the warmest months to an average of 30 days during the cooler months.

TABLE IX.—*Duration of larval instars of the citrus white fly.*

| Specimen No. | Period of growth. | Number of days in— | | | Sum of effective temperatures. | Specimen No. | Period of growth. | Number of days in— | | | Sum of effective temperatures. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Instar 1. | Instar 2. | Instar 3. | | | | Instar 1. | Instar 2. | Instar 3. | |
| 1 | Mar. 22–Apr. 26... | 13 | 10 | 12 | 1,044 | 33 | Oct. 3–Oct. 27.... | 7 | 5 | 12 | 736 |
| 2 | .....do..... | 11 | ..... | ..... | ..... | 34 | Oct. 3–Oct. 30.... | 5 | 8 | 14 | 811 |
| 3 | .....do..... | 9 | ..... | ..... | ..... | 35 | Oct. 3–Nov. 11.... | 7 | 15 | 17 | 1,102 |
| 4 | .....do..... | 10 | ..... | ..... | ..... | 36 | Oct. 3–Oct. 29.... | 7 | 8 | 11 | 792 |
| 5 | .....do..... | 11 | ..... | ..... | ..... | 37 | Oct. 3–Dec. 4..... | 31 | 14 | 17 | 1,644 |
| 6 | .....do..... | 9 | ..... | ..... | ..... | 38 | Oct. 3–Nov. 4..... | 12 | 7 | 13 | 922 |
| 7 | .....do..... | 9 | ..... | ..... | ..... | 39 | Oct. 3–Nov. 1..... | 8 | 8 | 13 | 843 |
| 8 | June 26–July 18... | 8 | 7 | 7 | 898 | 40 | Oct. 3–Nov. 2..... | 8 | 7 | 15 | 868 |
| 9 | June 26–July 19... | 8 | 5 | 10 | 938 | 41 | Oct. 3–Nov. 3..... | 9 | 7 | 15 | 894 |
| 10 | June 26–July 16... | 8 | 5 | 7 | 813 | 42 | .....do..... | 11 | 7 | 13 | 894 |
| 11 | June 26–July 18... | 7 | 6 | 9 | 898 | 43 | Oct. 3–Nov. 1..... | 8 | 8 | 13 | 843 |
| 12 | June 26–July 20... | 8 | 4 | 12 | 978 | 44 | Oct. 3–Nov. 10.... | 7 | 4 | 17 | 1,060 |
| 13 | June 26–July 18... | 8 | 5 | 9 | 898 | 45 | Oct. 3–Oct. 31.... | 8 | 8 | 12 | 828 |
| 14 | June 26–July 29... | 8 | 5 | 20 | 1,365 | 46 | Oct. 3–Nov. 4..... | 10 | 7 | 15 | 922 |
| 15 | June 26–July 18... | 8 | 5 | 9 | 898 | 47 | Oct. 3–Nov. 8..... | 7 | 7 | 22 | 1,012 |
| 16 | June 26–July 21... | 8 | 5 | 12 | 1,015 | 48 | .....do..... | 7 | 10 | 19 | 1,012 |
| 17 | June 26–July 18... | 8 | 5 | 9 | 898 | 49 | Oct. 3–Nov. 2..... | 7 | 9 | 14 | 868 |
| 18 | June 26–July 16... | 7 | 5 | 8 | 813 | 50 | Oct. 5–Nov. 1..... | 7 | 7 | 13 | 783 |
| 19 | June 26–July 18... | 8 | 5 | 9 | 898 | 51 | Oct. 5–Nov. 7..... | 5 | 17 | 11 | 932 |
| 20 | June 27–July 19... | 7 | 5 | 10 | 902 | 52 | Oct. 5–Oct. 31.... | 5 | 8 | 13 | 768 |
| 21 | June 27–July 20... | 8 | 5 | 10 | 942 | 53 | Oct. 5–Nov. 8..... | 8 | 8 | 18 | 952 |
| 22 | .....do..... | 7 | 8 | 8 | 942 | 54 | Oct. 5–Nov. 5..... | 9 | 8 | 14 | 883 |
| 23 | June 27–July 16... | 7 | 5 | 7 | 777 | 55 | Oct. 5–Nov. 1..... | 8 | 6 | 13 | 783 |
| 24 | June 28–July 21... | 6 | 6 | 11 | 938 | 56 | Oct. 5–Nov. 3..... | 9 | 8 | 12 | 834 |
| 25 | June 28–July 28... | 7 | 9 | 14 | 1,220 | 57 | Oct. 5–Nov. 5..... | 8 | 9 | 14 | 883 |
| 26 | June 28–July 18... | 6 | 5 | 9 | 821 | 58 | Oct. 5–Nov. 1..... | 10 | 6 | 11 | 783 |
| 27 | June 29–July 27... | 5 | 4 | 19 | 1,141 | 59 | Oct. 5–Nov. 19.... | 11 | 34 | died. | ..... |
| 28 | July 28–Aug. 18... | 5 | 4 | 12 | 866 | 60 | Oct. 5–Oct. 31.... | 6 | 8 | 13 | 767 |
| 29 | Sept. 28–Nov. 14.. | 7 | 16 | 30 | 1,365 | | | | | | |
| 30 | Sept. 30–Oct. 25... | 7 | 6 | 12 | 780 | Average.. | June 26–Aug. 18... | 7.2 | 5.4 | 10.5 | 945.7 |
| 31 | Sept. 30–Oct. 23... | 6 | 7 | 10 | 727 | | Sept. 28–Dec. 4... | [1] 7.8 | [2] 8.3 | 14.3 | 903.4 |
| 32 | Oct. 1–Oct. 21..... | 7 | 9 | 7 | 635 | | | | | | |

[1] Does not include No. 37.

[2] Does not include No. 59.




PUPA CASES OF THE CITRUS AND THE CLOUDY-WINGED WHITE FLIES.

Fig. 1.—Leaf showing pupa cases of *Aleyrodes citri;* also a few pupæ and eggs. Fig. 2.—Under surface of orange leaf, showing heavy infestation by citrus white fly. Fig. 3.—Leaf showing pupa cases of *A. nubifera.* Note delicate structure as compared with those of *A. citri.* (Original.)

PUPAL STAGE.

One of the most interesting phases of life-history studies has been the wide range in the duration of the pupal stage; a range of from 13 to 304 days. Considering the relatively slight variation in the length of the larval life, this range among specimens passing into the pupal stage at practically the same time is remarkable. In view of the fact that the effect of this variation upon the duration of life and number of annual generations will be fully discussed under those headings and brought out in Tables XV and XVII and figure 12, only a few of the large number of records on file are given in Table X to illustrate this range in pupal life during different parts of the year.

TABLE X.—*Duration of pupal stage of the citrus white fly.*

| Specimen No. | Period of growth. | Number of days. | Sum of effective temperatures. | Specimen No. | Period of growth. | Number of days. | Sum of effective temperatures. |
|---|---|---|---|---|---|---|---|
| 1 | Apr. 30–May 13..... | 13 | 410 | 11 | Aug. 15–Sept. 6.... | 22 | 885 |
| 2 | Apr. 30–June 20..... | 51 | 1,833 | 12 | Aug. 16–Mar. 18.... | 214 | 5,414 |
| 3 | Apr. 30–Aug. 3..... | 64 | 2,564 | 13 | Aug. 16–Mar. 20.... | 216 | 5,479 |
| 4 | May 18–June 5..... | 18 | 664 | 14 | Aug. 17–Mar. 25.... | 220 | 5,574 |
| 5 | May 18–July 31..... | 74 | 2,866 | 15 | Aug. 18–Sept. 10... | 23 | 931 |
| 6 | May 18–Mar. 18..... | 304 | ..... | 16 | Aug. 18–Apr. 1..... | 226 | 5,752 |
| 7 | July 15–July 30..... | 15 | 602 | 17 | Sept. 30–Mar. 31... | 182 | 4,473 |
| 8 | July 15–Aug. 4..... | 20 | 808 | 18 | Oct. 28–Apr. 19.... | 173 | 4,167 |
| 9 | Aug. 15–Aug. 27.... | 12 | 479 | 19 | Nov. 1–Apr. 17.... | 167 | 4,069 |
| 10 | Aug. 15–Aug. 28.... | 13 | 521 | 20 | Nov. 8–Mar. 25.... | 137 | 3,256 |

It will be noticed that pupæ pass either a comparatively few or a comparatively large number of days in this stage and that ordinary temperatures and humidity do not have the power to determine which it shall be.

LOCOMOTION.

On hatching from the egg the young larva is provided with well-developed legs, as shown in figure 5, by the aid of which it crawls about the leaf for several hours and then settles and begins to feed. Because of the aimless way in which it crawls, frequently doubling on its own course and turning aside for the least obstacle, it travels over a very limited area. It is therefore improbable that the crawling larvæ ever leave the leaf upon which they were hatched, unless carried on the feet of birds or insects or blown or dropped from one leaf to another. After settling, the larva does not change its position on the leaf, while with the first molt its legs become vestigial (see fig. 7) and unfit for locomotion. Larvæ frequently move slightly, especially directly after or during molting when they merely describe an arc of 180°, using their mouth parts as a pivot. The larva passes into the pupal stage without materially changing its position on the leaf. The only time, then, during the life cycle when the white fly is capable of moving about from place to place is during the winged adult stage and the crawling larval stage.

GROWTH.

Pronounced and striking growth in size occurs only at molting, when the soft flexible skin of the larva or pupa is able to stretch before assuming its normal rigid condition. With each successive molt the larva greatly increases its horizontal dimensions, until by the time it reaches the pupal stage these are about eighteen times as great as in the newly hatched larva. When first settled after molting the larva is very thin, papery, and transparent, being seen with difficulty except with the aid of a lens, but after feeding several days it slowly becomes thickened until, from two to five days, sometimes longer, before molting into the next instar, it is decidedly plump and whitish opaque in color. Oftentimes before molting the larva becomes very much swollen as though gorged with liquid. This appears to be an abnormal condition, since many that become thus unduly enlarged either fall or die without molting. During the increase in thickness following feeding, there is no increase in the horizontal dimensions. On the contrary, increase in the former is secured at a slight expense of the latter.

MOLTS.

Daily observations on over 300 marked individuals from time of settling to emergence of adult have conclusively demonstrated that the larva passes through but three instars [1] before reaching the pupal stage, instead of four as has been previously supposed. Each larva, then, molts or casts its skin three times before becoming a pupa. The process of molting was first described by Riley and Howard [2] and as observed by the authors is as follows:

> In preparing for a molt the insect curves the abdomen upwards at considerably more than a right angle, moving it also occasionally up and down. The margin of the abdomen has at the same time a slightly undulating motion. During these movements the insect is shrinking away from the lateral margin until it eventually occupies only about one-third of the original lateral space, causing a distinct dorsal and ventral median ridge. The skin then splits, not on the dorsum, as would be expected, but either at the anterior end or underneath the head. The head and prothorax are then pushed out and the skin is gradually worked backwards by means of the abdominal motions, the portion already out swelling as soon as it is free.

As the insect flattens after molting it appears milky white, the head, thoracic lobes, and abdominal segments being more greenish. At this time the legs, which resemble much the prolegs of a caterpillar, are very active, and there appears a pair of fleshy protuberances more or less movable, not as large as the legs, but apparently of the same

[1] This agrees with the senior author's observations on the greenhouse white fly (*A. vaporariorum*) and the strawberry white fly (*A. packardi*), which are the two species of the genus which have previously been studied in greatest detail. Tech. Bul. 1, Mass. Exp. Sta. and Can. Ent., vol. 35, pp. 25–35.

[2] Insect Life, vol. 5, p. 223, 1893.

structure, which act as sucking disks to aid the insect in reattaching itself. These protuberances are later withdrawn so that no trace of them remains. While becoming attached to the leaf the insect may be seen occasionally to rotate itself through an arc of 270°, in the meanwhile frequently raising and lowering the abdomen. The cast skins are usually blown away by the breeze or fall from the leaf as soon as molted, but not infrequently are found partially pinioned beneath the body of the insects. Molting occurs most actively during hours of high humidity. Newly molted larvæ are abundant during the early morning when the humidity ranges between 100° and 90°.

### FEEDING HABITS OF LARVÆ AND PUPÆ.

As the white flies, or Aleyrodidæ, belong to the Hemiptera, or sucking insects, the larvæ and pupæ do not eat the tissue of the leaf, but insert their thread-like mouthparts and suck the plant juices by the aid of a suction apparatus located in the head. Their ravages are not accompanied by any visible effect upon the leaf itself, but may be detected by means of the sooty mold which develops after the fly becomes very abundant. Our only means of estimating the amount of sap taken up by the insect is by the amount of waste material, or honeydew, ejected by it. A first-instar larva, on being watched under the compound microscope for 20 consecutive minutes with the temperature at 90° F., was seen to eject honeydew 48 times, or an average of about 10 times every 5 minutes. A pupa with well-developed eye-spots, in March, with the temperature at 85° F., ejected honeydew 4 times in 5 minutes. This difference in the amount of honeydew secreted is due in part to the different temperatures at which the observations were made as well as to the difference in the degree of development.

A very interesting observation on the amount of sap extracted by larvæ and pupæ of the white fly has been made by Dr. Berger[1] Leaves with live larvæ and pupæ were placed between glass plates so that the ejected honeydew was collected on the glass. By weighing it was found that each live insect had excreted about 0.0005 gram in 48 hours. At this rate a tree infested with 1,000,000 white-fly larvæ and pupæ would lose one-half pound of sap per day.

### THE ADULT.

The adult citrus white fly is very small, measuring only about one-sixteenth of an inch in length, and with a wing expanse of less than one-eighth of an inch. The natural color of the body, antennæ, legs, and wings is entirely obscured by secretions of delicate white wax particles, so that the insect appears snowy white (Pl. IX; text fig. 10, *a–i*)

[1] Bulletin 97, Florida Agricultural Experiment Station, pp. 63–64, 1909.

without spots or traces of darker shades upon the wings. Only the purple eyes are free from the white wax, and are in sharp contrast to the color of the rest of the body. A detailed description of the adult, by Riley and Howard, follows:

DESCRIPTION.[1]

♀.—Length, 1.4 mm.; expanse, 2.8 mm.; four-jointed rostrum about as stout as legs; joint 1 shortest, joint 2 longest, and about as long as 3 and 4 together; joint 3 somewhat longer than joint 1 and a little shorter than 4. Joint 1 of the 7-jointed antennæ very short, as broad as long, subcylindrical, slightly wider distally; joint 2 twice as long as 1, strongly clavate, and at tip somewhat broader than 1, bearing 3 or 4 short hairs arising from small tubercles; joint 3 longest, about twice as long as 2, slenderer than this and with a very narrow insertion, rather abruptly stouter at apical third, corrugated and terminating above in a small callosity resembling a similar organ in Phylloxera; joints 4

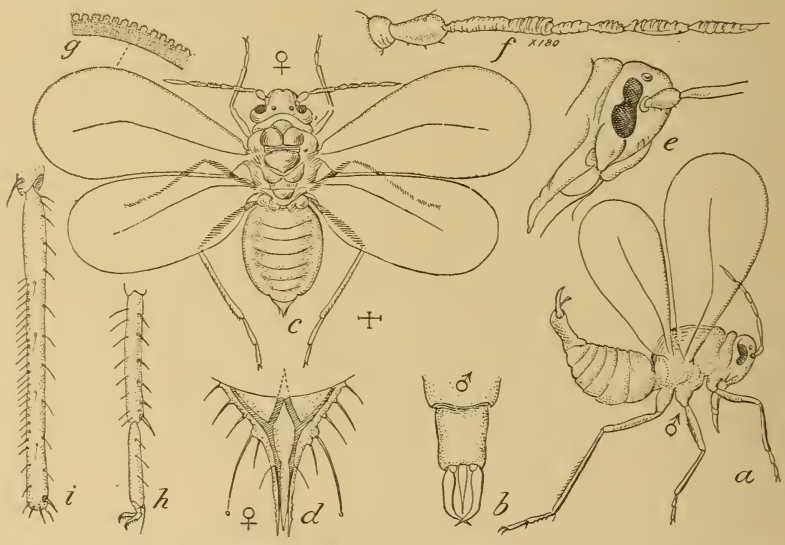



FIG. 10.—The citrus white fly. Adult. *a*, Male; *b*, claspers of male; *c*, female; *d*, ovipositor of female; *e*, side view of head of female; *f*, antenna; *g*, enlarged margin of wing; *h*, tarsus and claws; *i*, tibia. *a*, *c*, Greatly enlarged; *b*, *d*–*i*, more enlarged. (Adapted from Riley and Howard.)

and 5 subequal in length, each nearly as long as 2, joint 5 bearing a short spine anteriorly near apex; joints 6 and 7 subequal in length, each somewhat longer than 2, 7 with a stout spine at tip; joints 4 and 7 somewhat corrugate or annulate but less so than apical third of 3. The 2-jointed tarsi about half the length of the tibia, joint 1 of the hind tarsus bearing 6 rather stout spines on each side; joint 2 supporting at base 3 rather prominent claws, the middle one longest. Ovipositor short, acute, and retractile. Eyes divided into two by a curved pointed projection from middle of cheek, the upper portion being smaller than the lower portion. Wings clear, colorless; costa delicately serrate. General color, light orange yellow, tip of rostrum black, tarsi and part of tibia orange.

♂.—The male resembles the female in all important respects except in being smaller. Claspers about as long as preceding abdominal joint, or one-fifth the length

[1] Riley and Howard, Insect Life, vol. 5, p. 222, 1893.

ADULTS OF THE CITRUS WHITE FLY ON FOLIAGE OF ORANGE.

Fig. 1.—Tender growth swarming with adults. Fig. 2.—Leaf of same enlarged. (Original.)

of the abdomen, curved gently upward and inward, each bearing 4 or 5 equidistant minute cylindrical piliferous tubercles on upper and outer edge; style almost as long as claspers, rather stouter at base, more slender toward tip, terminating in a stout spine at upper end. Head and abdomen with heavy tufts of wax soon after issuing from pupa.

Examination of a large number of antennæ shows that the relative length of the antennal segments is subject to slight variations. The average relative lengths are about as follows:

| Segment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Spine. |
|---|---|---|---|---|---|---|---|---|
| spaces [1] | 10, | 24, | 43, | 16, | 16, | 18, | 22, | 3 |

Although they have examined thousands of males both at and for some time after emergence and as they occur at all times throughout the grove, the authors have never been able to observe males with the tufts of wax on head and abdomen mentioned in the above description and illustrated in connection with its original publication.

## EMERGENCE.

### DESCRIPTION OF THE PROCESS.

The emergence of the adult occurs soon after its purple eyes and folded whitish wings can be seen distinctly through the pupal skin. About 20 minutes before the pupal skin is ruptured the body of the adult shrinks gradually away from it and assumes its natural shape. This gradual shrinking away from the edges of the pupa, and the accompanying thickening of the body, brings a pressure to bear on the pupal skin which causes it to split from margin to margin between the thorax and abdomen and along the median line from this rupture to the anterior margin. Through the T-shaped opening thus formed the insect first pushes its thorax, then its head, with little apparent exertion. The body now projects almost perpendicularly from the pupa case, as the pupal skin is called, with the antennæ, legs, and abdomen still in their pupal envelopes. By a series of backward and forward movements the antennæ and legs are freed from their membranes and are in constant motion. The abdomen is now so nearly out of the pupal case that the fly is practically free, holding on only by means of the end of the abdomen. With a sudden forward bend of the body the legs are brought in contact with the leaf, and with their aid the fly frees the rest of its abdomen and crawls away rapidly.

The period covered between the time the insect ruptures the pupal skin and the time it becomes entirely free from the case and is crawling is from 7 to 10 minutes. Not infrequently flies die during emergence.

[1] These represent the spaces read on eyepiece micrometer when 1-inch eyepiece and $\frac{1}{6}$-inch objective are used, and the miscroscope tube is drawn to 160.

CHANGES AFTER EMERGENCE.

Immediately after emergence from the pupa case the adult differs from the more mature individuals in that the lemon-yellow color of the body is not obscured by the white waxy secretion that subsequently appears. Also the wings, which appeared as crumpled whitish pads when the thorax was first protruded from the pupa case, have had time only to partially expand. As the fly crawls away from the case the wings are held perpendicularly above the back, but as the wings gradually unfold and assume their normal shape they are lowered to their natural position. It requires about 7 minutes for the wings to become straightened after the fly leaves the case, and from about 14 to 17 minutes from the time they first begin to expand. When fully expanded, the wings are colorless and transparent, with the costa pale yellowish. The powdery whiteness so characteristic of the flies as seen in the grove gradually appears as the wax glands secrete their particles of wax. In about one and three-fourths hours the wings and body have become perfectly white.

CONDITIONS AFFECTING EMERGENCE.

Aside from that inherent influence affecting the development of the citrus white fly and determining whether the adult shall emerge during the first or second general emergence period, as hereinafter described under "Seasonal history," many field observations made at all seasons during the past three years, supplemented by laboratory experiments, have emphasized the great influence which temperature has on emergence. While a normal amount of humidity is necessary for emergence to occur, it is not so controlling a factor as temperature during ordinary Florida weather, as will be shown later. Light also seems to affect emergence under certain conditions.

EFFECT OF TEMPERATURE ON EMERGENCE.

Conclusions drawn from field notes, supplemented by laboratory experiments, show that emergence seldom occurs outside the range of 62° F. to 85° F., with preference to temperatures ranging from 70° to 85°. During the winter months of December, January, and February, when the average monthly mean is about 60° F., no emergence occurs except to a slight degree during warm spells of several days' duration. In January, 1906, when the average monthly mean temperature was 59.6°, or practically normal, no flies were noted on wing at Orlando, Fla., except in small trees beneath pinery sheds where the temperatures averaged several degrees higher than outside. During late December, 1908, and early January, 1909, the temperature had been sufficiently high to cause a limited amount of new growth to appear on some trees in Orlando, and on January 4 a comparatively large number of adult white flies were seen feeding and

depositing eggs on new growth in a very sheltered place. The average mean temperature of the 6 days preceding this observation was 66° F., while, for the 6 days preceding these, when no white flies were on wing, the average mean was about 58.5° F. Adult white flies were not seen in the laboratory grove in February, 1909, until about the 20th, or until the temperature records for the grove showed an average daily mean of about 64.5°. It is from the above facts that the lowest temperature at which emergence occurs has been determined to be about 62° F. This conclusion, drawn from general field observations, is strengthened by emergence records kept in connection with cage life-history work during the period of active spring emergence of March, 1908, when the monthly mean was 71°. Reference to the data contained in Table XI brings out the fact that while

TABLE XI.—*Relation of temperature to emergence of the citrus white fly.*

| Date. | Range in temperature. | Average mean temperature. | Emergence records. | | | |
|---|---|---|---|---|---|---|
| | | | No. 1. | No. 2. | No. 3. | No. 4. |
| 1908. | °F. | °F. | | | | |
| Mar. 19 | 62–89 | 75.5 | 4 | ..... | 6 | 2 |
| Mar. 20 | 63–90 | 76.5 | 5 | 18 | 78 | 4 |
| Mar. 21 | 54–65 | 59.5 | 0 | 0 | 1 | 1 |
| Mar. 22 | 60–80 | 70.0 | 10 | 15 | 69 | 15 |
| Mar. 23 | 66–90 | 78.0 | 17 | 35 | 71 | 4 |

emergence had been going on actively two days before and after March 21, when the average mean temperature was about 75° F., a drop in the mean temperature on the 21st to 59.5° F. practically prevented any white flies from emerging. The 1 white fly that is recorded under Nos. 3 and 4 may have emerged on the 20th after the daily record had been taken. Such emergences are not rare at this season of the year, as will be shown later. Of 2 lots of about 100 pupæ each, from which adults were nearly ready to emerge, 1 was placed in a refrigerator at about 56° F, and the other kept at room temperature which ranged between 70° F. and 80° F. while emergence was taking place. Of those kept on ice, but 1 white fly emerged during the first 12 hours, as compared with 17 from pupæ kept at room temperature. White flies continued to emerge on 3 consecutive days from pupæ kept at the latter temperature. No more emerged from the refrigerated pupæ. It is therefore evident that emergence may occur at as low a temperature as 56° F., though very rarely.

That white flies seldom emerge after the temperature reaches 85° F. may be concluded from the following facts: During the months of July and August, when the average daily mean is about 82° F., a newly emerged adult is rarely seen in the grove after 8 a. m. Prac-

tically all adults at this season emerge between 4 and 7 a. m. This is true both in the laboratory and in the grove. Of 233 white flies emerging separately in vials in the laboratory during August, 1907, 212 emerged between 3.30 and 8 a. m., and the remaining 21, with one exception, emerged between 8 and 9.30 a. m. In the grove over 95 per cent of the white flies emerge before 7 a. m. At this time of day the temperature ranges between 70° F. and 85° F. During the early spring, when the daily maximum temperature does not usually exceed 85°, emergence is not restricted to the early morning as during the heat of summer, but occurs at all times of the day. It may also be added that like conditions exist in October and November, but because of difference in seasonal history, they affect chiefly the spotted-wing white fly.

EFFECT OF HUMIDITY ON EMERGENCE.

Under normal Florida conditions at Orlando, at any season of the year, the relative humidity rises to nearly or quite 100 per cent by from 6 to 10 p. m., and there remains until about 6 a. m., when it normally drops rapidly, sometimes to as low as 19 per cent, though more often to from 35 to 60 per cent. It has already been stated that over 95 per cent of the white flies will have emerged before 7 a. m. or before the humidity has fallen far from the saturation point. That temperature and not humidity is the more important factor governing emergence in Florida, can be inferred by a comparison of the humidity and temperature records of Table XIII. It so happened that the cold wave of March 21, 1908, was accompanied by a higher average humidity, but the temperature and not the humidity prevented adults from emerging. Again, during the spring, when the daily maximum temperature is seldom above 85°—usually less—emergence goes on even at midday when the humidity has dropped to as low as 33°. In this connection attention should be called to the fact that the humidity in the corked vials mentioned under the preceding heading remained at about 100 per cent throughout the greater part of the experiment.

There are, however, times of abnormal weather conditions when lack of humidity seems to play an important part in preventing emergence. During the month of March there sometimes occur dry winds of several days' duration, accompanied by more or less heat, which seriously check emergence, and, as far as can be determined, cause many pupæ from which adults are about to emerge to die.

Two such periods occurred during March, 1909, from the 3d to the 6th, and from the 25th to the 27th, respectively. During these periods the relative humidity was extremely low, on one day dropping to 19 per cent. For 42 hours during the latter period the humidity ranged below 50 per cent and for 36 hours above 50 per cent. During

these periods emergence was noted to be seriously checked and at the end of the latter upward of 30 per cent of the pupæ were dead, apparently from no other cause.

EFFECT OF LIGHT ON EMERGENCE.

During the summer months light seems to have an influence on emergence. At this season emergence in the laboratory and grove begins at about daybreak. Observations made at hourly intervals on the emergence of 233 adults, from 3.30 and 4 a. m. show that white flies rarely emerge before this time. In one instance only about one-third as many white flies emerged from pupæ kept in the dark as from those kept in the open, and their emergence was noticeably delayed. During the cooler months the low morning temperatures prevent the white flies from responding to this apparent stimulation due to light, and they emerge at various times after the temperature has risen sufficiently high.

DURATION OF LIFE.

*Without food.*—In none of the experiments conducted to determine the length of adult life without food have white flies lived longer than 30 hours, and a very large percentage has died before the end of 24 hours. When confined on leaves of plants other than those recognized as food plants, life is usually longer than this, but never approaches the normal length. White flies confined on crape myrtle in July died as soon as those kept in empty cages, but flies caged on oak, in March, lived as long as 4 days; those on fig, in August, 3 days; and on banana shrub, in July, 2 to 3 days. In all these tests flies were placed only on the tenderest growth.

*With food.*—Adult life under normal outdoor conditions averages about 10 days, although individual white flies kept in cages have been known to live as long as 27 days. Adults are so fragile and so easily killed by winds and heavy showers and by numerous species of spiders and ants that their duration of life is at most very uncertain. Cage experiments during March, April, July, August, and September show that, in the cages at least, there is little difference in the length of life at various times of the year.

MATING.

The courtship of the citrus white fly has been observed to begin within 2 hours after emergence, and in one instance even before the wings of either male or female had become whitened. There is no time in the day when the males can not be seen courting the females. The male appears unable to locate the female at a distance much greater than one-fourth of an inch, according to Prof. H. A. Gossard. Observations made during the present investigations show that when males and females are placed in separate receptacles and separated

only by a very porous cheesecloth they show absolutely no attraction to each other. Mating, therefore, is not so likely to occur when the adults are scarce, as it seems to be the result of chance meeting upon the leaves rather than to such a definite attraction as exists between males and females of many moths.

Upon detecting the female, the male approaches her nervously, stopping at intervals, especially as the distance lessens, and swinging his body about excitedly in a semicircle, the head being used as a pivot, his wings in the meanwhile opening and closing spasmodically. While no movement is made by the female, she is repeatedly approached from many directions before coition occurs. More often the male lies alongside the female and courts her in this position, raising and lowering his wings as above described, and raising and swinging his abdomen from side to side. During these antics of the male the female remains quiet, only occasionally flittering her wings. While males may be seen courting females at all times of the day, it is seldom that one sees a pair in coitu except late in the afternoon and evening. Because of the uniformity of color and the ease with which adults are disturbed and made restless the duration of copulation can not be stated with certainty, but it probably lasts but a short time. Experiments to determine the duration of fertility have thus far proved unsuccessful.

### OVIPOSITION.

#### AGE AT BEGINNING OVIPOSITION.

Virgin females in confinement have deposited eggs within 6 hours after emergence. In one instance 35 virgins deposited 58 eggs between 5 and 9½ hours after emergence during summer weather, with the temperature ranging from 80° to 92° F. However, even at this temperature single females occasionally did not deposit eggs for over 24 hours. Prof. H. A. Gossard[1] states that egg laying begins at from 18 to 30 hours after the emergence when the temperature ranges from 65° to 75° F. Laboratory tests have shown that lack of fertilization does not prevent a female from depositing eggs, but that she will readily deposit infertile eggs until opportunity for mating presents itself.

#### PORTION OF PLANT SELECTED.

If not numerous, the females deposit almost exclusively on the under surface of the leaves, laying over 75 per cent of their eggs on the half of the leaf bordering the midrib. It is only when very abundant and pressed for room that they deposit eggs thickly over the entire lower surface and more sparingly on the upper surface, the petioles, and the stems of twigs. Next to the portion bordering the midrib, the natural depressions and the curled margins of the leaf, especially

[1] Bul. 67, Fla. Agr. Exp. Sta., p. 609, 1903.

of the tender growth, are favorite places for oviposition, and not infrequently as high as 40 per cent of the eggs are there laid, even when the adults are not very abundant. Although eggs may be deposited along the leaf margin, it is seldom that they are laid on the margin itself, as is the case with the cloudy-winged white fly. Even when not crowded for leaf space, the adults sometimes settle upon the under side of young fruit, where they deposit eggs freely and apparently feed.

DAILY RATE OF OVIPOSITION.

Previous to these investigations no data have been published on the daily rate of oviposition. In obtaining the data given in Table XII, the females recorded were collected at random throughout the grove, without regard to age, and, together with males not mentioned, were caged over leaves cleaned of all eggs and larvæ of the white fly and allowed to remain the recorded time, when the adults were removed and the eggs counted.

TABLE XII.—*Daily rate of oviposition of the citrus white fly.*

| Record No. | Date deposited. | Number of females. | Duration of egg laying. | Number of eggs deposited. | Average number of eggs per female per 24 hours. | Average mean temperature. |
|---|---|---|---|---|---|---|
| | | | *Hours.* | | | ° *F.* |
| 1 | Feb. 23–24, 1909 | 14 | 26 | 197 | 13 | 74.5 |
| 2 | Apr. 11–15, 1907 | 3 | 103 | 98 | 7.6 | 68.2 |
| 3 | Apr. 20–21, 1909 | 50 | 24 | 454 | 9.1 | 77.2 |
| 4 | Apr. 21–22, 1909 | 40 | 24 | 405 | 10.1 | 78.2 |
| 5 | June 16–17, 1909 | 30 | 24 | 360 | 12 | 82 |
| 6 | July 17–18, 1907 | 255 | 21 | 2,533 | 11.3 | 82 |
| 7 | July 22–23, 1907 | 105 | 24 | 1,216 | 11.6 | 85 |
| 8 | July 24–26, 1907 | 50 | 46 | 1,331 | 13.8 | 84 |
| 9 | Aug. 17–18, 1907 | 70 | 24 | 805 | 11.5 | 81 |
| 10 | Sept. 21–22, 1908 | 35 | 24 | 405 | 11.6 | 79 |

Number eggs per day per female, grand average, 11.2.

The generally uniform results obtained in the nine records when the average mean temperature was about 75° F. or above, together with the grand average daily rate of oviposition for individual females whose age was definitely known, as shown in Table XIII, indicate that each female normally deposits on an average 10 or 11 eggs a day. Varying degrees of temperature above a daily mean of 75° F. do not correspondingly increase the number of eggs deposited. However, temperatures below an average mean of 72° F. (estimated) have a distinct checking effect upon oviposition, as shown by record No. 2.

Notwithstanding the general average number of eggs per day deposited by the females of all ages in Table XII, and the same for the females of known ages for the total number of days they lived, in Table XIII, reference to the daily oviposition records in the latter

shows that as many as 14, 19, 27, or even 33 eggs may be deposited by a single female in one day. It will also be noted that much variation exists between the number of eggs deposited by several different females on the same day and by the same female on successive days without any apparent reason, and that there exists no appreciable difference between the rate of deposition by virgin and by fertilized females.

TABLE XIII.—*Number of eggs deposited by single females of the citrus white fly.*

| Fly No. | Date of first daily record. | Condition of female. | Daily rate of oviposition by individual females. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Aug. 8, 1907 | ♀+males 12 hours old | 8 | 19 | 9 | 22 | 11 | 2 | 15 | 6 | (1) | .... | .... | .... |
| 2 | .....do | .....do | 5 | 19 | 14 | 12 | 12 | 15 | 13 | 14 | (1) | .... | .... | .... |
| 3 | .....do | .....do | 3 | 9 | 13 | 5 | 13 | 9 | 16 | 8 | 1 | 15 | 19 | 14 |
| 4 | .....do | Virgin 12 hours old | 5 | 12 | 17 | 4 | 3 | 20 | 5 | 1 | 0 | 6 | 3 | 6 |
| 5 | Aug. 15, 1907 | Virgin 8 hours old | 5 | 13 | 15 | 14 | 12 | 12 | 15 | 13 | 14 | 10 | 9 | 9 |
| 6 | .....do | .....do | 6 | 16 | 17 | 5 | 33 | 13 | 23 | 16 | 15 | 14 | 10 | 3 |
| 7 | .....do | ♀+males 8 hours old | 8 | 8 | 16 | 14 | 17 | 11 | 16 | 7 | 1 | 4 | 2 | 4 |
| 8 | .....do | .....do | 2 | 18 | 16 | 14 | 9 | 2 | 13 | 15 | 6 | 9 | 9 | 1 |

| Fly No | Daily rate of oviposition by individual females. | | | | | | | | | | | | Total number of eggs laid. | Number of days lived. | Average number of eggs per day. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | | | |
| 1 | .... | .... | .... | .... | .... | .... | .... | ..... | ..... | ..... | ..... | ..... | 92 | 8 | 11.5 |
| 2 | .... | .... | .... | .... | .... | .... | .... | ..... | ..... | ..... | ..... | ..... | 104 | 8 | 13 |
| 3 | 13 | 9 | 5 | 14 | 10 | 8 | 6 | 9 | 6 | 1 | (1) | ..... | 206 | 22 | 9.4 |
| 4 | 5 | 10 | 2 | 2 | 3 | 0 | 8 | (2) | ..... | ..... | ..... | ..... | 112 | 19 | 6.0 |
| 5 | 5 | 20 | 11 | 2 | (3) | .... | .... | ..... | ..... | ..... | ..... | ..... | 179 | 16 | 11.2 |
| 6 | 19 | .... | 11 | 6 | 4 | (4) | .... | ..... | ..... | ..... | ..... | ..... | 211 | 17 | 12.4 |
| 7 | 8 | 3 | 14 | 12 | 2 | (1) | .... | ..... | ..... | ..... | ..... | ..... | 146 | 17 | 8.6 |
| 8 | 1 | 27 | 3 | (5) | .... | .... | .... | ..... | ..... | ..... | ..... | ..... | 144 | 14 | 10.3 |

[1] Dead.
[2] Dead; 13 eggs in abdomen.
[3] Dead; 18 eggs in abdomen.
[4] Dead; 11 eggs in abdomen.
[5] Dead; 7 eggs in abdomen.

Number of eggs per day per female, grand average, 10.3.

The eight records in Table XIII are selected from about forty similar records on file and are considered as representing an average condition of oviposition. Although the general average of 10.3 eggs per day throughout life for the 8 females recorded in Table XIII agrees very closely with the similar average obtained in Table XII, there is sufficient evidence in the data in Table XIII to warrant the statement that the daily rate of oviposition for individual females is usually greater during the early part of the insect's life and decreases with each successive week of existence. Leaving out of consideration the first day, when the flies had not reached their normal egg-laying capacity, a little calculation shows that the average daily deposition for the three successive weeks is 12.8, 8.5, and 6.1, respectively. This same decrease in the number of eggs deposited with increase in age is perhaps better brought out by a study of the number of eggs deposited by the individual females over 5-day periods. Thus No. 6 averaged 16.2 eggs per day for the first 10 days, but for

the next 5 dropped to an average of 7.8; Nos. 4 and 7 showed a sharp falling off during the second 5 days. No. 3 is an exception to the above statement, maintaining an average of from 9.8 to 11.8 eggs per day for the first three periods of 5 days each, and during the fourth period of 5 days deposited as many eggs as during the first 5 days. It will be noticed, however, that No. 3 deposited comparatively few eggs during the early part of her life. In view of the fact that the average adult life is only about 10 days, the higher rate of deposition during early life has an influence on multiplication.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES.

First mention of the egg-laying capacity of the citrus white fly was made by Riley and Howard,[1] who based their conclusions on the number of eggs that could be counted in the abdomen of the females when mounted in balsam, and not upon daily counts of eggs deposited by the females throughout life. Their estimate of about 25 eggs as the probable total number of eggs deposited by a single female during life has been generally accepted by subsequent writers, none of whom has ever placed the maximum number deposited above this figure. The present investigations, however, have demonstrated that this estimate is far too low and that the number of well-developed eggs to be found in the abdomen of the female at any one time is not indicative of the number of eggs deposited throughout her life. Females have been known to deposit more than this number of eggs in a single day. As will be seen by reference to Table XIII, as many as 211 eggs have been actually deposited by one female, and should the 11 well-developed eggs found in her abdomen at death be added a total of 222 eggs would be obtained. As this female, No. 6, lived but 17 days and others have been known to live 28 days, it is even probable that as many as 250 eggs more nearly represent the maximum egg-laying capacity under most favorable conditions. However, it is seldom that a female lives sufficiently long to deposit her full quota of eggs. With the average length of adult life curtailed to about 10 days, the average of 149.2 eggs per female, as shown in Table XIII, is beyond doubt high. An average of 125 eggs per female is nearer the number of eggs deposited during life in the grove.

ACTIVITY IN OVIPOSITION DURING DIFFERENT PARTS OF THE DAY.

In order to determine that portion of the day when eggs are most freely deposited by females during summer weather, adults were inclosed in a rearing cage over leaves from which all previously deposited eggs had been removed, and allowed to remain for a period of two hours, when the cage with adults was removed to another leaf and the deposited eggs counted, with results shown in Table XIV.

[1] Insect Life, vol. 5, p. 222, 1893.

TABLE XIV.—*Activity of the citrus white fly in oviposition during different parts of the day.*

| Time of day. | Mean temperature for period. | Number of eggs deposited. | Per cent of total eggs deposited. |
|---|---|---|---|
| | ° *F.* | | |
| 6 a. m.–8 a. m. | 82 | 20 | 2.6 |
| 8 a. m.–10 a. m. | 89 | 55 | 7.3 |
| 10 a. m.–12 m. | 91 | 35 | 4.7 |
| 12 m.–2 p. m. | 92 | 65 | 8.7 |
| 2 p. m.–4 p. m. | 90 | 30 | 4 |
| 4 p. m.–6 p. m. | 85 | 197 | 26.1 |
| 6 p. m.–8 p. m. | 81 | 248 | 32.9 |
| 8 p. m.–6 a. m. | 74 | 103 | 13.7 |
| 6 a. m.–6. a. m. | [1] 81.6 | 753 | 100 |

[1] Average temperature for entire day of 24 hours; not the average of the 8 periods.

From the data it will be seen that while oviposition occurs at all times of the day, nearly 60 per cent of the eggs are deposited between 4 p. m. and 8 p. m., and that oviposition does not cease on the approach of darkness. The variation in the number of eggs deposited during the periods from 6 a. m. to 4 p. m. has little significance. It was noted that the least number of eggs were deposited when the bright sun fell directly upon the cage.

In further evidence of the greater activity of oviposition during the latter part of the day, two other cages were started on August 1, 1909. One cage placed repeatedly over the tenderest growth resulted in 698 eggs being laid between 10.15 a. m. and 4.15 p. m., as compared with 895 eggs laid between 4.30 p. m. and 7.30 p. m. The second cage, covering spring growth, gave 115 as compared with 786 eggs deposited during the same periods.

*Relation between oviposition and food supply.*—As the egg-laying capacity of a single female is close to 250 eggs and but 25 well-developed eggs have ever been seen in her abdomen at any one time, it is necessary that she obtain nourishment sufficient to mature her numerous "potential" eggs. There remain many interesting observations and experiments to be made on the relation between oviposition and food supply. That females deposit fewer eggs when feeding upon many of the recognized food plants other than citrus than they do on the latter is a subject of considerable interest. While adults feed apparently as contentedly upon new growth of China trees and umbrella China trees, they do not appear to deposit as many eggs per female on these host plants as on citrus. The extremely small number of eggs laid by females swarming over new growth of wild persimmon in June at Orlando is even more astonishing considering the marked preference shown by the females for this growth over the spring growth of orange. Even on citrus itself oviposition is influenced by the ages and corresponding toughness of the leaves, though not as markedly as is that of the cloudy-winged white fly. In one instance equal numbers of adults were confined on a tender and an

old leaf of orange for two hours, when the adults were removed and 576 eggs were found to have been laid on the tender leaf and but 25 on the old leaf. Again, under practically the same conditions, 364 eggs were deposited upon tender growth and but 2 on very old growth. The difference between oviposition on tender August growth and spring growth is not as great as this, though very marked, as about 90 per cent of the third-brood adults fly to the new growth put on by the trees late in July and early in August.

From the foregoing it is evident that the number of eggs deposited is strongly influenced by the nature of the insect's food. Females confined in empty cages never deposit eggs, neither do those resting upon thick bark, ladders, or picking boxes, and, as has been stated under "Food plants," oviposition is entirely checked[1] when females are confined with leaves of nonfood plants. This difference in the number of eggs deposited on various plants may prove of value from the standpoint of trap foods, and become a factor in the control of this pest.

### PROPORTION OF SEXES.

Examination of thousands of adult citrus white flies at all seasons of the year has shown that after a grove has become well infested an equilibrium between the proportion of males and females is established from which there is under ordinary conditions little variation. In such groves it has been found that from 60 to 75 per cent of the adults are females. Of the records on file, about 66 per cent give percentages of 60 and over for females, while 66 to 76 per cent are more frequent percentages where adults are abundant.

In groves where the progress of the white fly has been very seriously and suddenly checked by natural or artificial causes, the proportion of sexes is subject to a much wider variation and there follow for a time fluctuations between a predominance of males and females. In one such grove where the white fly had been greatly reduced in numbers because of the scarcity of adults of the first brood, there was a very large percentage of males appearing with the second brood, which in turn resulted in the third brood of 90.5 per cent females. In a second grove, where over 99 per cent of the white fly were killed by fumigation, the few females of the first brood, because of their isolation due to scarcity in numbers, were forced to deposit mostly infertile eggs, which resulted, in the second brood, in a reduction of females to 18.6 per cent.

*Dependence of sex upon parthenogenesis.*—The proportion between the sexes is largely and evidently entirely dependent upon parthenogenesis. It has been shown that infertile females deposit eggs in as

[1] Three hundred adults of *A. citri* confined on the tenderest spring growth of oak for three days deposited 1 egg.

large numbers and as frequently when males are not given access to them as do fertile females, and that the adults developing from these eggs are all males. Whether the adults from fertile eggs are invariably females has not been proved, although the evidence leaves little doubt that they are. If otherwise, it would be difficult to account for the fluctuations in sexes mentioned under the preceding heading, or to explain the great predominance of females over males after the species has become well established.

### INFLUENCE OF WEATHER CONDITIONS ON ACTIVITY OF ADULTS.

During the cooler portions of the year, when adults are present on the trees, very few are seen flying about from tree to tree unless abundant. The morning and evening temperatures easily chill them; hence their activities are confined to the warmer part of the day.

However, after summer weather has become established the white flies rest very quietly on the under surface of the leaves during the greater part of the day. They shun the bright sunshine and prefer leaves in shaded places. When exposed to the sun without protection they soon die. As the temperature falls during the late afternoon, and especially after afternoon showers when the humidity has risen to 90° or even to 100°, they become very active, and about 4 o'clock begin to fly about from leaf to leaf and from tree to tree, and, when very abundant, swarm in such large numbers about the groves and town streets as to arrest the attention of pedestrians, to whom they become at times a source of much aggravation, becoming entangled in the hair, crushed upon the clothing, breathed in with the air and causing choking, and flying into the eyes.

### FEEDING HABITS OF ADULTS.

The adult insects, having well-developed sucking mouth parts, feed upon the plant juices in the same manner as do the larvæ and pupæ, but with the advantages of not being confined to the same location. They do not leave any external evidence of the feeding except on very young growth, when the feeding of a large number of adults frequently produces a crinkling of the foliage.

It is difficult to determine positively whether or not an adult citrus white fly is feeding when it is resting on a leaf or stem. Adults rest contentedly during the warm portions of the day upon the underside of leaves of plants upon which they have never been known to deposit eggs. Under these circumstances they even appear to mate, and it seems probable that they feed to a limited extent. When on one of the principal food plants of the species, however, it is safe to consider that adults feed wherever eggs are deposited in noticeable numbers. It is because of this indiscriminate settling upon vegetation upon which they are not able to subsist, and upon which they

never breed, that the belief has received such an unfortunately wide circulation among orange growers that the citrus white fly breeds on all kinds of hammock trees, shrubs, and grasses. Regardless of the food plant, the adults feed almost exclusively upon the under surface of the leaves, more rarely upon the fruit, and never upon the woody portions of the tree. When new growth is very young and the leaves have not expanded, adults often feed upon both surfaces of the leaf, the petiole, and even the tender shoots, but this lasts only for a short time. At all seasons the newest growth is preferred, as indicated by the data under the caption of the relation of food supply to oviposition, and the portion of the plant selected coincides with that already discussed for oviposition. It should be noted here that the decided preference of the adults for the new growth has a checking effect, as noted elsewhere, upon multiplication, as they are entirely lacking in instincts preventing over-oviposition

### Multiplication.

The relation of multiplication to food supply and the restrictions upon multiplication due to overcrowding, natural mortality, dropping of leaves after freezes, parthenogenesis, and attacks by insects and other predaceous enemies and fungi will be found treated elsewhere. It has been estimated that not more than 5 per cent, at the most, of the eggs deposited throughout the State result in the development of mature insects. If each female deposited her full number of eggs and all the forms lived, it has been estimated, the progeny of a single pair of white flies emerging in January would amount to about 55,000,000,000 in one year.

### Length of Life Cycle.

Data concerning the duration of the egg, larval, and pupal instars of the citrus white fly have already been given, but not in a form readily showing the relation to the complete life cycle. From some of the more important and complete of the life-history studies the data in Table XV have been arranged to illustrate the important points in this connection:

Table XV.—*Length of life cycle of the citrus white fly at Orlando, Fla.*

| Lot No. | Eggs deposited. | First fly emerged. | Last fly emerged in fall. | First fly emerged in spring. | Last fly emerged. |
|---|---|---|---|---|---|
| No. 1 | Feb. 23 | Apr. 30 | ..... | ..... | ..... |
| No. 2 | Mar. 3 | May 9 | ..... | ..... | ..... |
| No. 3 | Apr. 3 | May 30 | ..... | ..... | ..... |
| No. 4 | Apr. 20 | June 7 | ..... | ..... | Mar. 18 |
| No. 5 | June 16 | July 30 | ..... | ..... | ..... |
| No. 6 | July 17 | Aug. 27 | Sept. 10 | Mar. 16 | Apr. 16 |
| No. 7 | ...do..... | Sept. 4 | Sept. 17 | Mar. 17 | May 4 |
| No. 8 | July 19 | Sept. 2 | Sept. 21 | ...do..... | May 1 |
| No. 9 | July 26 | Sept. 6 | Sept. 20 | Mar. 18 | May 10 |
| No. 10 | Aug. 1 | Sept. 19 | Sept. 26 | Mar. 24 | Apr. 6 |
| No. 11 | Aug. 3 | Sept. 25 | ...do..... | Mar. 23 | Apr. 15 |
| No. 12 | Aug. 8 | Sept. 19 | Sept. 27 | ..... | ..... |
| No. 13 | Aug. 9 | Mar. 30 | 0 | Mar. 20 | May 12 |
| No. 14 | Sept. 18 | Mar. 16 | 0 | Mar. 16 | Apr. 28 |
| No. 15 | Sept. 21 | Mar. 12 | 0 | Mar. 12 | May 10 |

| Lot No. | Least number of days for development. | Largest number of days for development. | Per cent emerging before winter. | Per cent wintering over to emerge in spring. | Smallest number degrees effective temperature for development. | Degrees accumulating before spring emergence. | Degrees accumulating before last fly emerged. |
|---|---|---|---|---|---|---|---|
| No. 1 | 67 | ..... | 100.0 | 0 | 1,783 | ..... | ..... |
| No. 2 | 67 | ..... | 100.0 | 0 | 1,885 | ..... | ..... |
| No. 3 | 57 | ..... | 100.0 | 0 | 1,888 | ..... | ..... |
| No. 4 | 48 | 333 | ..... | ..... | 1,712 | ..... | ..... |
| No. 5 | 44 | ..... | ..... | ..... | 1,725 | ..... | ..... |
| No. 6 | 41 | 273 | 56.9 | 43.1 | 1,641 | 6,632 | 7,619 |
| No. 7 | 49 | 291 | 30.8 | 69.2 | 1,972 | 6,665 | 8,253 |
| No. 8 | 45 | 286 | 12.7 | 87.3 | 1,815 | 6,504 | 8,059 |
| No. 9 | 42 | 288 | 29.8 | 70.2 | 1,703 | 6,322 | 7,981 |
| No. 10 | 49 | 248 | 5.5 | 94.5 | 2,015 | 6,255 | 6,654 |
| No. 11 | 53 | 255 | 3.6 | 96.4 | 2,153 | 6,107 | 6,858 |
| No. 12 | 42 | ..... | 2.7 | 97.3 | 1,735 | ..... | ..... |
| No. 13 | 223 | 276 | 0 | 100.0 | 5,825 | 5,825 | 7,545 |
| No. 14 | 179 | 222 | 0 | 100.0 | 4,552 | 4,552 | 5,836 |
| No. 15 | 172 | 231 | 0 | 100.0 | 4,289 | 4,289 | 6,100 |

From this table it will be seen that the period of development for individuals hatching from eggs laid upon the same leaf within a few hours of each other is subject to an astonishing variation, ranging from 41 to 333 days. This variation is absolutely independent of both temperature and humidity influences. It will be noted that the sums of effective temperatures required for the minimum duration of immature stages for individuals developing from eggs deposited between February 23 and August 8 vary from 1,641° to 2,153°, with an average of 1,846°, which may be regarded as very nearly the normal for minimum development up to the time when

all individuals winter over as pupæ. It should also be noted that the number of maximum degrees of effective temperature is more strongly influenced by the time of year the eggs are deposited—the nearer the winter months deposition takes place the fewer the degrees accumulating before the last fly emerges. This is due to the equalizing effect of the cooler winter temperatures.

This same equalizing effect of the winter temperatures upon the length of the life cycle for individuals developing from eggs laid on September 20 is brought out in Table XVI:

TABLE XVI.—*Duration of instars of the citrus white fly.*

| Specimen No. | Instar. | | | | | | | | Total number of days. |
|---|---|---|---|---|---|---|---|---|---|
| | First. | | Second. | | Third. | | Pupal. | | |
| | Duration of instar. | Number of days. | Duration of instar. | Number of days. | Duration of instar. | Number of days. | Duration of instar. | Number of days. | |
| | 1908. | | 1908. | | 1908. | | 1908. | | |
| 1 | Oct. 3–10 | 8 | Oct. 10–15 | 5 | Oct. 15–27 | 12 | Oct. 27–Apr. 28 | 173 | 198 |
| 2 | Oct. 3–10 | 8 | Oct. 10–24 | 14 | Oct. 24–Nov. 10 | 17 | Nov. 10–Apr. 17 | 158 | 197 |
| 3 | Oct. 3–15 | 13 | Oct. 15–22 | 7 | Oct. 22–Nov. 4 | 13 | Nov. 4–Apr. 8 | 155 | 188 |
| 4 | Oct. 3–Nov. 2 | 31 | Nov. 2–16 | 14 | Nov. 16–Dec. 3 | 17 | Dec. 3–Apr. 6 | 128 | 190 |
| 5 | Oct. 3–10 | 8 | Oct. 10–18 | 8 | Oct. 18–29 | 11 | Oct. 29–Mar. 26 | 148 | 175 |

From this table it will be seen that retardation in growth during any one instar does not affect materially or show a corresponding increase in the total number of days required for development when the individual passes the winter in the pupal stage. Also, that an unusually large number of days spent in one instar does not necessarily mean that the individual insect will be equally backward in the next instar. These records of daily observation on individual specimens from hatching to adult are only 5 of 85 similar observations for the same period. Nos. 2–5 were insects on the same leaf.

## SEASONAL HISTORY.

### GENERATIONS OF THE CITRUS WHITE FLY.

It has been generally understood in the past that there are three generations annually of the citrus white fly, although Prof. H. A. Gossard,[1] states that "four generations a year doubtless often occur, but not in sufficient numbers to obscure three well-defined broods as the rule." In the greenhouses at Washington, Riley and Howard[2] found that there were but two generations annually. The life-history work of the present investigations has shown that while the general

[1] Bul. 67, Fla. Agr. Exp. Sta., p. 612, 1903.

[2] Insect Life, vol. 5, p. 224, 1893.

observations of the past leading to the statement of three more or less distinct periods of emergence are correct, the number of generations annually ranges from two to five, or, under unusually favorable conditions, from three to six. In figure 11 the maximum and minimum number of generations as actually known to occur in groves at Orlando during 1907–9 has been plotted. Figure 11 is based upon the development of individuals in rearing experiments. The generation between January and March may or may not occur, according to whether the winter weather is warm or cold, but when present is numerically insignificant. The other generations are more confused than can be indicated diagrammatically. As may

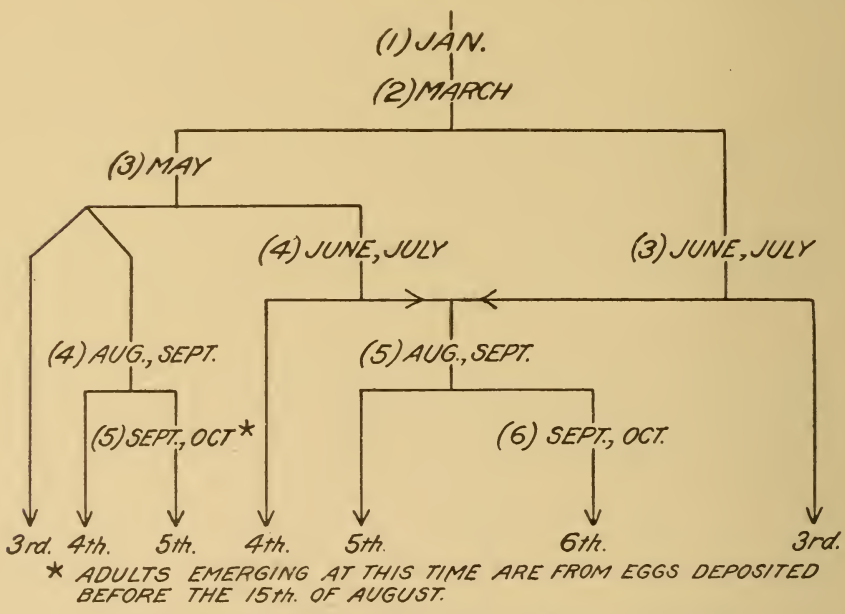



FIG 11.—Diagram showing generations of the citrus white fly. (Original.)

have been inferred from data in Tables XV and XVII, the variation in the number of generations is due almost entirely to the length of the pupal stage, which, as has already been pointed out, is subject to wide variation, the cause of which can not be traced to food, temperature, humidity, or location on the tree. The most striking variation in the length of life cycle, with its effect upon the possible number of annual generations, is found among individuals developing from eggs deposited in April and May. In one instance eggs deposited on April 20 produced adults on June 5, July 31, and in the following March. In the main, each generation has two more or less distinct periods of emergence, as reference to the data in Tables XV and XVII will show.

TABLE XVII.—*Emergence of adult citrus white flies at Orlando, Fla.*[1]

| Record No. | Eggs deposited. | April. | | May. | | June. | | July | | August. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1–15 | 16–30 | 1–15 | 16–31 | 1–15 | 16–30 | 1–15 | 16–31 | 1–15 | 16–31 |
| 1 | Feb. 22 | 0 | 1 | 85 | | | | | | | |
| 2 | Mar. 3 | 0 | 0 | 44 | 44 | | | | | | |
| 3 | Mar. 18–25 | 0 | 0 | 1 | 51 | 30.3 | 2.9 | 0 | 4.9 | 9.9 | 0 |
| 4 | Apr. 20 | 0 | 0 | 0 | 0 | 50.1 | 28.6 | 0 | 8.2 | 0 | 0 |
| 5 | June 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (3) | | |
| 6 | July 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32.1 |
| 7 | July 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | July 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | July 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Aug. 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Aug. 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Aug. 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | Sept. 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | Sept. 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Record No. | Eggs deposited. | September. | | October to March. | March. | | April. | | May. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1–15 | 16–30 | | 1–15 | 16–31 | 1–15 | 16–30 | 1–15 | 16–30 |
| 1 | Feb. 22 | | | | | | | | | |
| 2 | Mar. 3 | | | | | | | | | |
| 3 | Mar. 18–25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Apr. 20 | 0 | (2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | June 16 | | | | | | | | | |
| 6 | July 17 | 24.4 | 0.4 | 0 | 0 | 43.1 | 0 | 0 | 0 | 0 |
| 7 | July 17 | 23.9 | 6.9 | 0 | 0 | 67.3 | 1.9 | 0 | 0 | 0 |
| 8 | July 19 | 8.7 | 1.7 | 0 | 0 | 89.2 | .4 | 0 | 0 | 0 |
| 9 | July 26 | 23.8 | 6.5 | 0 | 0 | 64.3 | 5.4 | 0 | 0 | 0 |
| 10 | Aug. 1 | 0 | 3.3 | 0 | 0 | 85.6 | 11.1 | 0 | 0 | 0 |
| 11 | Aug. 8 | 0 | 2.7 | 0 | 0 | | | | | |
| 12 | Aug. 9 | 0 | 0 | 0 | 0 | 98.7 | 1.3 | 0 | 0 | 0 |
| 13 | Sept. 18 | 0 | 0 | 0 | 0 | 38.3 | 46.8 | 14.9 | 0 | 0 |
| 14 | Sept. 21 | 0 | 0 | 0 | 0 | 38.6 | 47 | 14.7 | 0 | 0 |

[1] This table is introduced to demonstrate the two emergence periods for individuals developing from eggs deposited at the same time. It is not intended to represent the abundance of adults at different times of the year. Figures represent percentages.

[2] Only one fly survived to winter over.

[3] One fly emerged July 30. Leaf was broken off on same day. Development of flies indicated that at least 50 per cent would have emerged during August.

This makes it possible for adults emerging during the first period to deposit eggs for a second generation, a portion of the adults of which (first brood) will emerge at the time of the second emergence period (second brood) for the first generation, while a large proportion of the remaining individuals on the leaf to all appearances remain stationary in their development, though actively secreting honeydew, until the approach of the first emergence period of the second generation started by the second brood of the first generation, when they rapidly mature and emerge with this brood. However, this double-brooded character of each generation up to and including generations started in early August does not obscure the three well-defined "broods" of adults, to be discussed under "Seasonal fluctuations in the numbers of adults or so-called 'broods,'" but shows that the adults appearing during the three general emergence periods do not, strictly speaking, represent a single brood of one generation, but different broods of different generations. By far the greater number

of wintering-over pupæ belong to the fourth, fifth, and sixth generations, with the last two most abundantly represented. The number of third-generation pupæ—or second generation should the first generation in figure 11 not occur—to winter over is insignificant.

### Seasonal Fluctuations in the Numbers of Adults or so-called "Broods."

During winters of unusual mildness there is a tendency for continuous breeding, and adults in varying numbers can be found on the wing at different times, but these are as a rule too few in number to be of importance in effecting the general seasonal history of the citrus white fly. With the exception of the limited number of larvæ developing from eggs deposited by these unseasonal adults, the white fly passes the winter in the pupal stage. The first general spring emergence of adults begins after the daily mean temperatures have risen to about 65° F., which at Orlando in 1909 was about February 20.

There are three periods throughout the year when adult citrus white flies are so much more abundant than at other seasons that it is generally said there are three broods of white flies each year,

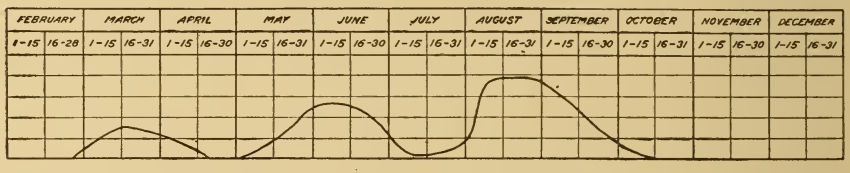



Fig. 12.—Diagram showing abundance of adults of the citrus white fly at Orlando, Fla., throughout 1909. (Original.)

although, as already noted under the subject of generations, the term brood in this case is somewhat misleading. The dates at which these adults appear is subject to such variation in groves in the same county, town, or even on individual trees of the same grove, that no accurate statement of the dates between which the broods occur throughout the State as a whole can be made. The authors, therefore, have chosen to follow the history of the white fly in a single grove at Orlando during the season of 1909 as a specific example, as a basis, and present in figure 12 a curve representing the abundance of adults throughout that season. In all its essential features the curve is regarded as representing the appearance of adults in any grove, when it is remembered that variations of from one to three or four weeks may occur in the appearance of the broods.

While it is generally believed that adults appear earlier in the spring throughout southern Florida, it is a fact that there is very little difference in time of emergence between that and the central portion. Emergence throughout the northern portion of the State is, according to the season, from one to four weeks later than in the central and

southern portions. Prof. H. A. Gossard has stated that at Lake City in 1902 white flies began to appear no earlier than April 14, and continued to appear until late in May, although the majority of them emerged during the latter half of April, while in 1903 the same trees produced adults as early as March 12, or but one week later than groves at Orlando and Palmetto. While the spring brood of adults at Orlando in 1909 had begun to emerge as early as February 20 and had reached their height and begun to decline by March 27, on the latter date in St. Augustine only 5 per cent of the pupæ had developed the eyes of the adult and practically no adults had emerged. Professor Gossard also is authority for the statement that at "Tampa, 30 to 40 miles north of the Manatee section, the spring brood of white flies has in some seasons preceded their appearance about Bradentown and Manatee by two weeks." By June 18, 1909, more than twice as many adults of the second brood had emerged at Manatee as at Island Grove about 125 miles north in Alachua County, while by July 7 of the same year the white fly in a grove at Alva in Lee County was no further advanced than at Orlando.

From the curve in figure 12 it will be noticed that there are two periods of about three weeks during the summer between the broods when adults are comparatively very scarce. While reference to Table XVII shows that a few wintering-over individuals continue to emerge as late as early May, the period between the first and second broods of adults is exceptionally free from adults of the citrus white fly. This, however, is not true of the like period between the second and third broods as before this time the generations of the white fly have become somewhat confused, due to variation in life cycle, and adults continue to emerge in appreciable numbers throughout the period.

In speaking of the entire citrus belt, including Florida and the Gulf States, the greater part of the spring brood may be said to emerge during March and April; the second brood to emerge during late May, June, and July, and the third brood during August and September. It should be noted here that the greater part of the adult white flies appearing in October and November in the central and southern part of Florida are the cloudy-winged white fly, *A. nubifera*, although in the northern part adult specimens of *A. citri* have been seen in small numbers on the wing in St. Augustine as late as November 15.

## THE CLOUDY-WINGED WHITE FLY.

(*Aleyrodes nubifera* Berger.)

### HISTORY.

Specimens of the cloudy-winged white fly (eggs, larvæ, and pupæ) in the collection of the Bureau of Entomology show that this species occurred on oranges in the United States as early as 1889. The records in connection with the specimens show that it was collected in Mississippi and North Carolina in 1889, in Louisiana in 1890, and in Florida in 1895. Outside of the United States it is known to occur only in Cuba. Its introduction into the United States from Cuba does not seem as probable as its introduction into Cuba from the United States. At present there is no evidence concerning the probable origin of the insect except in the absence, so far as is known, of other food plants than citrus, which would seem to indicate the introduction of the insect with its only known food plant.[1]

Several writings on the citrus white fly (*Aleyrodes citri*) have in part included the cloudy-winged white fly (*A. nubifera*). Prof. H. A. Morgan,[2] in 1893, previous to the publication of the original description of *Aleyrodes citri*, briefly described the egg of *Aleyrodes nubifera* and figured it, the description of the pupa and adult given at the same time evidently being based on specimens of *A. citri*. The species to which Prof. Morgan referred the specimens was *Aleyrodes citrifolii* Riley MS. The original description of the citrus white fly,[3] while unquestionably defining the species generally recognized as *A. citri*, included in part reference to what is probably the spotted-wing white fly. In the text the description of the first stage or instar of the larva was evidently based on a specimen of the spotted-wing white fly and the illustration of the first instar [4] was also based on this species with little doubt. One figure of the pupa [5] and one of the pupa case [6] evidently were based upon specimens of the same species. In the writings of Prof. Gossard there are no references in the text which evidently refer to the cloudy-winged white fly, but what is probably this species is represented in an illustration of the first stage.[7]

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[1] Its recent discovery on *Ficus nitida*, rubber tree, in greenhouses at Audubon Park, New Orleans, La., points to its possible introduction from India.

[2] The Orange and Other Citrus Fruits. Special Bulletin Louisiana Agricultural Experiment Station, p. 72, 1893.

[3] Insect Life, vol. 5, pp. 220–222, 1893.

[4] Id., vol. 5, p. 219, fig. 23, *d*.

[5] Id., vol. 5, p. 219, fig. 23, *h*.

[6] Id., vol. 5, p. 219, fig. 23, *i*.

[7] Bulletin 67, Florida Agricultural Experiment Station, pl. 2, fig. 1. See also Bulletin 88, pl. 2, fig. 1, and Bulletin 97, fig. 11, Florida Agricultural Experiment Station, and Circular 30, California Agricultural Experiment Station, pl. 2, fig. 1.

The white fly known as the cloudy-winged white fly was first determined as specifically distinct from the citrus white fly by Dr. E. W. Berger in 1908. Dr. Berger has recently given this species its scientific name in connection with a synopsis of the principal distinctive characters and illustrations of egg and larval and pupal stages.[1]

### AMOUNT OF INJURY BY THE CLOUDY-WINGED WHITE FLY.

The injury caused by the cloudy-winged white fly is at present much restricted by several factors. In Florida the distribution of this species is limited as compared with that of the citrus white fly. Its food-plant differences and adaptations are such that orange trees[2] are not as a rule subject to as heavy infestations as by the citrus white fly, although with grapefruit trees this situation is usually reversed. Most important as a factor limiting the injury from the cloudy winged white fly is that when both occur in an orange grove the citrus white fly almost invariably predominates and the cloudy-winged white fly assumes a position of comparative insignificance. Owing to the difference in the seasonal history of the two species of white fly this latter point is not always apparent to the casual observer. An observation made between the broods of adults of the citrus white fly, or at any time after the middle of September up to December 1, may result in noting a great preponderance of the cloudy-winged white fly, leading one to conclude, perhaps, that it is this latter species which is causing the most injury. An examination of the leaves during the winter months, when there are practically no adults of either species, will probably show an entirely different situation. In many groves near Orlando and Winter Park in Orange County, Fla., both species of white fly are well established and practically have assumed their normal relative positions in point of numbers. Examinations of leaves varying in number from 85 to 400 pinched at random in 11 of such groves furnish data which illustrate the general situation as regards the importance of the two species of white fly under the conditions mentioned. (See Table XVIII.) All the examinations were made during the winter months, using pupa cases and live pupæ as the basis of the comparison.

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[1] Bulletin 97, Florida Agricultural Experiment Station pp. 68–70, figs. 12, 14, 16, 18, 19.

[2] According to the latest statistics available (Ninth Biennial Report of Commissioner of Agriculture, State of Florida) there were more than five times as many orange trees as grapefruit in Florida, 1,786,944 orange trees being reported for 1905 as against 373,008 grapefruit trees.

TABLE XVIII.—*Comparative abundance of Aleyrodes citri and Aleyrodes nubifera in groves infested by both species.*

| Grove Nos. | Tangerine. | | Grapefruit. | | Orange. | | Grapefruit and orange. | |
|---|---|---|---|---|---|---|---|---|
| | Citri per leaf. | Nubifera per leaf. | Citri per leaf. | Nubifera per leaf. | Citri per leaf. | Nubifera per leaf. | Citri per leaf. | Nubifera per leaf. |
| 1 | 44.2 | 7.5 | 1.6 | 1.4 | | | | |
| 2 | | | | | 33.2 | 0.5 | | |
| 3 | | | | | 4 | 1.2 | | |
| 4 | | | | | 14.5 | .4 | | |
| 5 | | | | | 4.6 | .2 | | |
| 6 | | | 8.8 | 2.4 | | | | |
| 7 | | | | | | | 11.2 | 1.1 |
| 8 | | | | | | | 21. | 1.6 |
| 9 | | | | | 33 | .56 | | |
| 10 | | | | | 30 | 7. | | |
| 11 | .9 | .2 | .8 | 3.7 | | | | |
| Average. | 22.5 | 3.6 | 3.7 | 2.5 | 19.9 | .59 | 16.1 | 1.3 |
| Per cent | 86.7 | 13.3 | 59.6 | 40.3 | 97.7 | 2.3 | 92.6 | 7.4 |

Owing to the great attraction of new growth for the cloudy-winged white fly, which is discussed elsewhere, the scarcity of new citrus growth at certain seasons which causes concentration on water shoots, and other factors, this species, when it occurs by itself in a tangerine or orange grove, does not as frequently as the citrus white fly cause noticeable blackening of the foliage before the middle of June. At the end of the season the cloudy-winged white fly by itself may cause tangerine and orange trees to become as heavily blackened with sooty mold as the citrus white fly when the latter is at its greatest abundance. As has been stated, the cloudy-winged white fly is more likely to heavily infest grapefruit trees than is the citrus white fly. The cloudy-winged white fly seems to be subject to more extensive fluctuations from year to year, aside from the effects of fungus parasites, than is the citrus white fly, and frequently after infesting an orange grove for several years fails to cause enough injury to make washing of the fruit necessary or to make necessary the washing of more than one-fourth or one-third of the crop each year.

As a whole, the injury is not as extensive in groves where the cloudy-winged white fly occurs alone as in groves where the citrus white fly occurs alone. When the two species become well established, the former does comparatively little damage except to grapefruit. The authors would estimate that there are about 5 per cent of the orange and tangerine groves in the State infested by the cloudy-winged white fly that are not also infested by the citrus white fly, and that there are in addition 1 per cent of orange and tangerine groves infested by both species but in which the citrus white fly has not as yet attained injurious abundance. The average damage from the cloudy-winged white fly is estimated at about 10 to 15 per cent lower for oranges where that species alone infests the grove than where the citrus white fly is the species concerned. For

injury to grapefruit the authors consider 25 per cent a fair estimate of the injury by the cloudy-winged white fly as compared with about 10 or 15 per cent by the citrus white fly. The total loss in Florida due to the cloudy-winged white fly is estimated by the authors at between $100,000 and $125,000 per annum at the present time.

## DISTRIBUTION.

So far as known at the present writing the cloudy-winged white fly occurs in 12 counties in Florida. The locality list is given below:[1]

Brevard County: Mims, Sharpes, Titusville.
Dade County: Miami.
Hillsboro County: Riverview, Thonotosassa, Ybor City, Clearwater, Dunedin, Largo, Ozona, Safety Harbor, Saint Petersburg, Sutherland.
Manatee County: Bradentown, Oneco, Palmetto.
Monroe County: Key West.
Orange County: Geneva, Maitland, Ocoee, Orlando, Oviedo, Waco, Winter Park.
Palm Beach County: Palm Beach, West Palmbeach.
Polk County: Auburndale, Bartow, Lakeland, Winterhaven.
St. Lucie County: Fort Pierce.
Sumter County: Wildwood.
Volusia County: Haw Creek, Holly Hill, Port Orange, Pierson.

Outside of the State of Florida the only available records of the occurrence of the cloudy-winged white fly are those of the Bureau of Entomology in connection with specimens in the collection. Mr. A. L. Quaintance has identified as this species specimens from New Orleans (1890) and Baton Rouge, La. (1891), Pass Christian, Miss. (1889), and Raleigh, N. C. (1889). In a brief examination at Audubon Park, New Orleans, in August, 1909, the senior author was unable to find any evidence of the presence of this species, although the citrus white fly was prevalent on citrus trees, privets, and other food plants.

As stated in the footnote on page 27, the species occurring at Bakersfield, Cal., in 1907 was the cloudy-winged white-fly. Owing to the fact that the insect is, so far as known, confined to citrus as a food plant and only a limited number of these in an isolated location were infested, the thorough measures adopted by the agents of the State commissioner of horticulture met with complete success, and there is no record of this species occurring at present in this State.

Its occurrence in Cuba has already been noted, specimens having been received from Santiago de las Vegas in 1905.

The distribution of the cloudy-winged white fly in Florida, so far as now known, is shown in figure 13. The territory included in the

[1] The authors have determined as *Aleyrodes nubifera* specimens from all of the localities listed above except the following, which are listed upon the authority of Dr. E. W. Berger: Holly Hill, Ybor City, Bartow, Clearwater, and Safety Harbor.

infested area is not generally infested, and the same precautions should be observed within this area as outside of it to avoid unnecessary spread of the pest.

## FOOD PLANTS.

The cloudy-winged white fly is not known in Florida to breed upon any other food plant than citrus. It has recently been discovered infesting the rubber trees (*Ficus nitida*) growing in the greenhouses in Audubon Park, New Orleans. Extensive examinations for possible food plants have been made by the authors and by Dr. Berger, and it is reasonably certain that no important food plant will be found in Florida citrus-growing sections which will interfere with the control of this species.

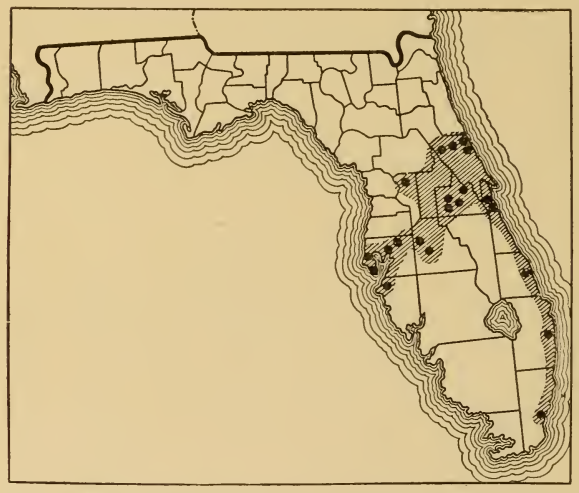


FIG. 13.—Map showing distribution of the cloudy-winged white fly (*Aleyrodes nubifera*) in Florida. (Original.)

Examinations of prickly ash (*Xanthoxylum clava-herculis*), the most common representative of the family Rutaceæ to which the citrus belongs, indicate that this species of white fly never breeds on this plant, regardless of the condition of infestation of neighboring citrus trees. Reports of blackening of the foliage of prickly ash by the white fly in sections where only the cloudy-winged white fly of the two herein treated occurs, are doubtless erroneous and probably based upon the blackening due to an aphis or to some other insect. In addition the following plants have been examined under favorable conditions to determine if subject to attack by the cloudy-winged white fly, but so far without results:

China trees and umbrella China trees, cape jessamine, privets, Japan and wild persimmons, oaks, wild cherry, guava, fig, grape, cherry laurel, blackberry, and magnolia.

## SPREAD.

The dissemination of the cloudy-winged white fly is limited by the same factors which have been discussed as unfavorable to the successful establishment of the citrus white fly. Aside from these factors

its chief limitation is in its lack of important food plants other than citrus. Migrations of adults are not an important factor in the spread of this white fly except between adjoining groves. Its spread throughout a newly infested grove and to adjoining groves is perhaps favored by its greater degree of attraction to new growth. It has been observed frequently in newly infested groves that it is found to be present in very small numbers over a considerable area, whereas the citrus white fly, when at a corresponding numerical status, would be expected to be more localized. Winds are doubtless concerned with the spread of the insect from local centers, but, as with the citrus white fly, they are evidently a factor of small consequence in spread to distant points.

Flying insects and birds as carriers of the crawling larvæ are necessarily of little or no consequence in the spread of the cloudy-winged white fly, as with the species previously discussed. Between groves vehicles of various kinds are of much importance in distributing this white fly, as is generally recognized. Without doubt infested citrus nursery stock has been the principal factor in the spread of the spotted-wing white fly. Nursery stock from Mims, Fla., is quite definitely known to have been the source of this white fly at Sharpes, Fla. At the present time it seems to be the most probable source of this white fly at Fort Pierce, Palm Beach, and Miami.

FIG. 14.—The cloudy-winged white fly: Eggs. Greatly enlarged. (Original.)

The species here considered are apparently as likely to be carried on the person from an infested grove as is the citrus white fly, the degree of infestation being equal. The same may be said of pickers' outfits. The introduction of fungus-infected leaves into groves infested only by the citrus white fly in connection with the introduction of fungus parasites has doubtless assisted in the spread of the cloudy-winged white fly, but not to the same extent that this has assisted in the spread of the former species.

## LIFE HISTORY AND HABITS.

### THE EGG.

The egg (fig. 14) of the cloudy-winged white fly differs from that of the citrus white fly in that it is not greenish-yellow and highly polished, but bluish or grayish black and roughened by a film of wax arranged in an hexagonal pattern. To the unaided eye the eggs appear as fine particles of blackish dust scattered over the leaves (Pl. X, fig. 1). Because of their dark color they are more readily seen on the tender citrus growth by the average observer than are the eggs of the citrus white fly. When first deposited they are not blackish, but are dull white or cream colored and under the micro-

scope the waxy coating appears tinged with red. The eggs remain pale for three days, when about 96 per cent turn black, the rest taking sometimes as long as seven or eight days to darken. Meanwhile the waxy coating has turned gray. Because of the dark color and much tougher chorion, the eyes of the embryo are not as easily seen as are those of the citrus white fly. The eggs are attached to the leaf by a pedicel arising from the proximal end similar to that of *A. citri*.

A study of the contents of Tables VIII and XIX will prove that what has been said of the duration of the egg stage, variability under identical temperature conditions, and effect of temperature in general, regarding the citrus white fly, applies almost equally well to this species.

TABLE XIX.—*Duration of egg stage of the cloudy-winged white fly.*

| Record No. | Date deposited. | Eggs under observation. | First egg hatched. | Last egg hatched. | Least number days. | Largest number days. | Daily rate of hatching of eggs of the cloudy-winged white fly in percentages, with accumulative effective temperatures. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 8 days. | ° F. | 9 days. | ° F. | 10 days. | ° F. | 11 days. | ° F. | 12 days. | ° F. |
| 1 | Apr. 20, 1909. | 345 | May 2 | May 7 | 12 | 17 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 4.1 | 422 |
| 2 | June 16, 1909. | 849 | June 26 | July 1 | 11 | 16 | 0 | ..... | 0 | ..... | 0 | ..... | 0.5 | 383 | 4.9 | 424 |
| 3 | Aug. 23, 1909. | 276 | Sept. 3 | Sept. 7 | 11 | 15 | 0 | ..... | 0 | ..... | 0 | ..... | 63.4 | 457 | 21.4 | 496 |
| 4 | Sept. 4, 1907. | 146 | Sept. 14 | Sept. 19 | 10 | 15 | 0 | ..... | 0 | ..... | 3.4 | 351 | 73.9 | 390 | ..... | 428 |
| 5 | Sept. 18–21, 1908. | 171 | Sept. 26 | Oct. 3 | 8 | 12–16 | 2.4 | 282 | 0 | 318 | 1.1 | 355 | 1.1 | 389 | 13.5 | 424 |
| 6 | Sept. 21, 1908. | 325 | Oct. 1 | Oct. 9 | 10 | 18 | 0 | ..... | 0 | ..... | .3 | 349 | 1.5 | 385 | 40.7 | 415 |
| 7 | Oct. 9–11, 1908. | 898 | Oct. 23 | Oct. 29 | 14 | 18–20 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... |

| Record No. | Daily rate of hatching of eggs of the cloudy-winged white fly in percentages, with accumulative effective temperatures. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 days. | ° F. | 14 days. | ° F. | 15 days. | ° F. | 16 days. | ° F. | 17 days. | ° F. | 18 days. | ° F. | 19 days. | ° F. | 20 days. | ° F. |
| 1 | 32.8 | 442 | 48.0 | 470 | 7.7 | 500 | 5.0 | 531 | 2.4 | 564 | 0 | ..... | 0 | ..... | ..... | ..... |
| 2 | 45.5 | 462 | 44.9 | 496 | 4.0 | 532 | .2 | 569 | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 3 | 4.3 | 534 | 7.3 | 571 | 3.6 | 610 | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 4 | 19.8 | 466 | 2.1 | 501 | .8 | 539 | 0 | ..... | 0 | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 5 | 35.1 | 460 | 43.3 | 493 | 3.5 | 523 | 0 | ..... | 0 | ..... | 0 | ..... | 0 | ..... | ..... | ..... |
| 6 | 34.3 | 445 | 15.4 | 477 | 3.2 | 507 | 2.8 | 538 | 1.2 | 570 | 0.6 | 601 | 0 | ..... | 0 | ..... |
| 7 | 0 | ..... | .8 | 407 | 6.7 | 432 | 43.8 | 460 | 37.6 | 490 | 8.3 | 520 | 1.9 | 551 | 0.8 | 576 |

The duration of the egg stage, however, is in general slightly longer. As the bulk of the eggs hatch from 1 to 10 days later, a slightly higher number of degrees of accumulated effective temperature are necessary, and hatching is more evenly distributed though not always extending over a larger number of days.

The process of hatching, proportion of eggs that hatch, and the effect of drying of leaves in hatching do not appreciably differ from what has been stated of *A. citri;* in hatching, however, the egg membranes split only about one-third the length of the egg from the tip and on one side only, and on account of the tougher chorion do not shrivel, but retain their original form. Frequently, after the larva has escaped, the membranes spring back into their original position, thus causing the eggs to appear unhatched; as a rule, however, this does not occur, and the opening made by the escaping larva does not close. While no adults have yet been reared from larvæ hatching from infertile eggs, it has been proved that virgin females of the cloudy-winged white fly will deposit eggs and that these readily hatch and produce healthy larvæ, and the evidence in case of the citrus and greenhouse white flies leaves no doubt that adults resulting from infertile eggs will prove to be of the male sex.

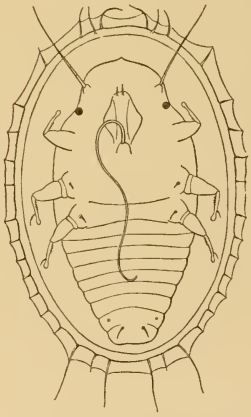


Fig. 15.—The cloudy-winged white fly: Ventral view of crawling larva of the first instar. Greatly enlarged. (Original.)

## The Larval and Pupal Stages.

### THE LARVA.

The larva of the cloudy-winged white fly does not differ in general appearance from that of the citrus white fly except that it is a trifle larger. With the aid of the microscope the first instar may be separated from that of *A. citri* by the possession of 36 instead of 30 marginal bristles. No structural differences between the second and third instars of the two species have been discovered. Following is a more detailed comparative description:

*First larval instar* (fig. 15).—Length, 0.29–0.32 mm.; width, 0.19–0.22 mm. Similar to the corresponding instar of *A. citri*, but differing in being proportionately broader, in possessing 18 instead of 15 pairs of marginal bristles, and in developing soon after settling a marginal irregular wax fringe eventually equaling in width the length of the marginal spines. Relative length of marginal spines as follows:

| Pair | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Spaces | 10.5 | 7.5 | 10.5 | 8.5 | 7.0 | 5.5 | 6.0 | 5.0 | 6.0 |
| Pair | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Spaces | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.5 | 15.5 | 6.5 | 15.5 |

The relative lengths and location of other spines of the body do not differ from similar spines on *A. citri*, neither do there appear differences in the structure of the antennæ, legs, vasiform orifice, or mouthparts when examined under a one-sixth inch objective. Particles of wax secretions are found in varying amounts on the ventral surface, sometimes in such abundance as to make microscopic examinations difficult.

*Second larval instar.*—Length, 0.42–0.51 mm.; width 0.28–0.37 mm. Except in point of size no differences have been discovered between this and the corresponding instar of *A. citri*.

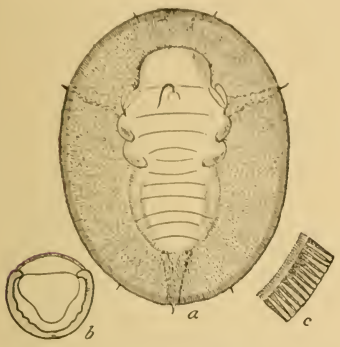



FIG. 17.—The cloudy-winged white fly. Pupa: *a*, Ventral view; *b*, enlarged vasiform orifice; *c*, enlarged margin. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

*Third larval instar* (fig. 16).—Length, 0.66–0.9 mm.; width, 0.48–0.68 mm. Except in size no differences have been discovered between this and the corresponding instar of *A. citri*.

FIG. 16.—The cloudy-winged white fly: Ventral view of crawling larva of the third instar. Greatly enlarged. (Original.)

THE PUPA.

In general appearance the pupa of the cloudy-winged white fly (fig. 17, *a*, *b*, *c*) resembles very closely that of the citrus white fly. No striking structural differences have been discovered between them. They are, however, very distinct, and one who has examined them carefully can readily separate them without the aid of a lens. The most important differences are in the larger size and thinner and flatter appearance of the pupa of the cloudy-winged white fly. The difference in outline is shown in figs. 9, *c*, and 17, *c*. Their skins are more membranous, making them more delicate and easily crumpled. Furthermore, after thickening before maturity they do not develop the bright red or orange spot on the middle of their backs, and the wing pads and body of the adult (fig. 18) are more easily seen. The pupa case (Pl. VIII, fig. 3) is much thinner, more membranous, and falls from the leaf more readily. Its walls do not remain rigid as do those of *A. citri*, but because of their more delicate structure collapse after the emergence of the adult and present the crinkled appearance shown in the illustration.

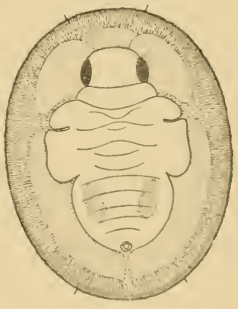


FIG. 18.—The cloudy-winged white-fly: Dorsal view of pupa, showing adult insect about to emerge. Greatly enlarged. (Original.)

DURATION OF INSTARS.

*Larval instars.*—By comparing the data in Tables IX and XX it will be found that the larvæ of *A. nubifera* are slower in maturing than those of *A. citri*. While this difference is not so pronounced during the warmer months of the year, the total average number of days being 25.9 and 23.1, respectively, during the cooler months it is very striking, the total average number of days then being 56.7 for *A. nubifera*, as compared with 30.4 for *A. citri*. In other respects the statements made on the duration of the larval instars for *A. citri* apply to *A. nubifera*.

TABLE XX.—*Duration of larval instars of cloudy-winged white fly.*

| Specimen No. | Period of growth. | Number of days in— | | | Sum of effective temperature. | Specimen No. | Period of growth. | Number of days in— | | | Sum of effective temperature. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Instar 1. | Instar 2. | Instar 3. | | | | Instar 1. | Instar 2. | Instar 3. | |
| 1 | June 26–July 19... | 9 | 6 | 8 | 938 | 33 | Sept. 30–Nov. 20.. | 8 | 15 | 28 | 1,322 |
| 2 | June 27–July 20... | 6 | 6 | 11 | 942 | 34 | Sept. 30–Nov. 23.. | 11 | 12 | 31 | 1,401 |
| 3 | June 27–July 21... | 8 | 6 | 10 | 979 | 35 | Sept. 30–Dec. 20.. | 11 | 14 | 46 | 1,831 |
| 4 | June 27–July 26... | 9 | 7 | 13 | 1,179 | 36 | Sept. 30–Dec. 3... | 8 | 19 | 37 | 1,670 |
| 5 | June 27–July 19... | 9 | 7 | 6 | 902 | 37 | Sept. 30–Nov. 23.. | 8 | 14 | 32 | 1,401 |
| 6 | June 27–July 21... | 8 | 8 | 8 | 979 | 38 | Sept. 30–Dec. 3... | 11 | 12 | 42 | 1,670 |
| 7 | June 27–July 17... | 7 | 6 | 7 | 820 | 39 | Sept. 30–Nov. 27.. | 9 | 9 | 40 | 1,513 |
| 8 | June 27–July 19... | 5 | 7 | 10 | 902 | 40 | .....do..... | 8 | 14 | 36 | 1,513 |
| 9 | June 27–July 20... | 7 | 6 | 10 | 942 | 41 | Sept. 30–Dec. 3... | 8 | 14 | 42 | 1,670 |
| 10 | .....do..... | 7 | 6 | 10 | 942 | 42 | Sept. 30–Nov. 23.. | 9 | 11 | 34 | 1,513 |
| 11 | June 27–July 21... | 7 | 6 | 11 | 979 | 43 | Sept. 30–Dec. 10.. | 8 | 15 | 48 | 1,831 |
| 12 | June 27–July 19... | 7 | 6 | 9 | 902 | 44 | Sept. 30–Dec. 3... | 8 | 14 | 42 | 1,670 |
| 13 | June 28–July 27... | 14 | 8 | 7 | 1,179 | 45 | Oct. 2–Dec. 7..... | 10 | 9 | 47 | 1,704 |
| 14 | June 28–July 29... | 7 | 6 | 18 | 1,260 | 46 | Oct. 2–Nov. 10.... | 7 | 9 | 21 | 1,060 |
| 15 | June 28–July 24... | 11 | 8 | 7 | 1,056 | 47 | Oct. 2–Nov. 30.... | 8 | 23 | 26 | 1,524 |
| 16 | June 28–July —... | 9 | 21 | ..... | ..... | 48 | Oct. 2–Nov. 19.... | 9 | 10 | 27 | 1,235 |
| 17 | June 28–July 19... | 6 | 6 | 9 | 861 | 49 | .....do..... | 7 | 12 | 27 | 1,235 |
| 18 | June 28–July 24... | 7 | 9 | 10 | 1,056 | 50 | Oct. 2–Nov. 23.... | 8 | 9 | 33 | 1,332 |
| 19 | June 29–July 29... | 6 | 15 | 9 | 1,222 | 51 | Oct. 2–Nov. 19.... | 7 | 11 | 28 | 1,235 |
| 20 | June 29–July 24... | 7 | 7 | 11 | 1,018 | 52 | Oct. 3–Nov. 27.... | 11 | 18 | 27 | 1,414 |
| 21 | June 29–July 29... | 8 | 8 | 14 | 1,222 | 53 | Oct. 3–Dec. 3..... | 10 | 17 | 35 | 1,561 |
| 22 | June 30–July 30... | 8 | 8 | 14 | 1,229 | 54 | Oct. 3–Dec. 7..... | 10 | 16 | 40 | 1,662 |
| 23 | June 30–July 29... | 12 | 7 | 10 | 1,188 | 55 | Oct. 3–Dec. 2..... | 10 | 23 | 28 | 1,536 |
| 24 | Sept. 30–Nov. 1... | 5 | 10 | 18 | 912 | 56 | Oct. 3–Dec. 1..... | 10 | 15 | 35 | 1,510 |
| 25 | Sept. 30–Nov. 20.. | 8 | 16 | 28 | 1,322 | 57 | Oct. 3–Dec. 3..... | 11 | 20 | 33 | 1,561 |
| 26 | Sept. 30–Nov. 30.. | 12 | 12 | 38 | 1,593 | 58 | .....do..... | 11 | 20 | 31 | 1,561 |
| 27 | .....do..... | 14 | 15 | 33 | 1,593 | 59 | Oct. 5–Nov. 11.... | 9 | 11 | 18 | 1,000 |
| 28 | Sept. 30–Dec. 3... | 12 | 23 | 32 | 1,670 | 60 | Oct. 5–Dec. 10.... | 66 | died. | ..... | ..... |
| 29 | Sept. 30–Nov. 3... | 8 | 10 | 17 | 963 | | | | | | |
| 30 | Sept. 30–Dec. 3... | 8 | 21 | 35 | 1,670 | Average. | June 26–July 30... | 8 | 7.8 | 10.1 | 1,031.7 |
| 31 | Sept. 30–Nov. 30.. | 8 | 13 | 40 | 1,593 | | Sept. 30–Dec. 10.. | 9.1 | 14.4 | 33.2 | 1,475.6 |
| 32 | Sept. 30–Dec. 3... | 8 | 14 | 42 | 1,670 | | | | | | |

*Pupal instar.*—That little difference exists between the length of the pupal stages of the two species of white fly in question is shown by a comparison of the data in Tables X and XXI. The minimum length of the pupal stage (17 days) will average but a trifle above that of *A. citri*. But the maximum length is so dependent upon the seasonal history that a direct comparison is difficult; this subject, therefore, is more profitably discussed under the caption of seasonal history. What has been said in connection with the maturing of specimens of *A. citri* passing into the pupal stage at practically the same time is equally true of the cloudy-winged white fly, *A. nubifera*.

TABLE XXI.—*Duration of pupal stage of cloudy-winged white fly.*

| Specimen No. | Period of growth. | Number of days. | Sum of effective temperature. | Specimen No. | Period of growth. | Number of days. | Sum of effective temperature. |
|---|---|---|---|---|---|---|---|
| 1 | May 24–June 11 | 18 | 694 | 11 | Oct. 12–Mar. 27 | 167 | 3,709 |
| 2 | May 26–June 14 | 19 | 741 | 12 | Oct. 31–Mar. 23 | 23 | 2,893 |
| 3 | May 26–July 19 | 24 | 2,107 | 13 | Nov. 1–Mar. 25 | 145 | 2,920 |
| 4 | May 26. | | | 14 | Nov. 14–May 29 | 196 | 5,102 |
| 5 | July 16[1]–Aug. 2 | 17 | 689 | 15 | Nov. 20–May 4 | 165 | 4,318 |
| 6 | July 18–Aug. 5 | 18 | 714 | 16 | Nov. 23–Mar. 28 | 125 | 2,981 |
| 7 | Oct. 9–Oct. 26 | 17 | 466 | 17 | Dec. 3–Mar. 27 | 114 | 2,702 |
| 8 | Oct. 9–Oct. 28 | 18 | 519 | 18 | Dec. 3–Apr. 29 | 147 | 3,662 |
| 9 | Oct. 9–Oct. 30 | 21 | 562 | 19 | Dec. 7–Mar. 28 | 111 | 2,681 |
| 10 | Oct. 9–Oct. 26 | 17 | 466 | 20 | Dec. 11–Mar. 24 | 104 | 2,476 |

[1] It is to be regretted that the falling of the leaf upon which Nos. 5 and 6 matured prevented gathering data on the maximum length of stage at this season of year.

GROWTH, MOLTS, LOCOMOTION, AND FEEDING HABITS.

Concerning growth, molts, locomotion, and feeding habits, there is little to add to that already stated in connection with the larvæ and pupæ of the citrus white fly. The two species are alike as regards the number of larval instars and in their crawling and sedentary habits. Their manner of feeding is similar also, with the exception that when crowded the larvæ of the cloudy-winged white fly settle freely upon the upper surfaces of shaded leaves, where they frequently reach maturity.

MORTALITY AMONG LARVÆ AND PUPÆ.

Remarks relating to mortality among the larvæ and pupæ of the citrus white fly apply with greater force to the cloudy-winged white fly. This mortality appears to result from the same causes in the latter as in the former species. Life-history work has shown that mortality due to spring droughts and dropping from leaves is practically the same for the two species, but that general mortality including "unexplained" mortality is about 3 per cent higher for *A. nubifera*. In this last respect, however, observations throughout groves where infestation is much heavier than on leaves used in the life-history work, and counts of forms on leaves infested with both species of fly, show that the comparative susceptibility to the influences producing mortality of all kinds is often at least twenty times greater for *A. nubifera*. This greater susceptibility appears to be due not only to the more delicate structure of the larvæ and pupæ and their need of more room for development because of their larger size, but also to the adults' habit of crowding the new growth with eggs far beyond its capacity for maturing the larvæ hatching therefrom.

As may have been inferred already from statements upon the subject of oviposition, it is this insatiable desire of the adults for feeding and ovipositing on new growth that is a most powerful factor leading to the insect's control. While a large amount of data might here

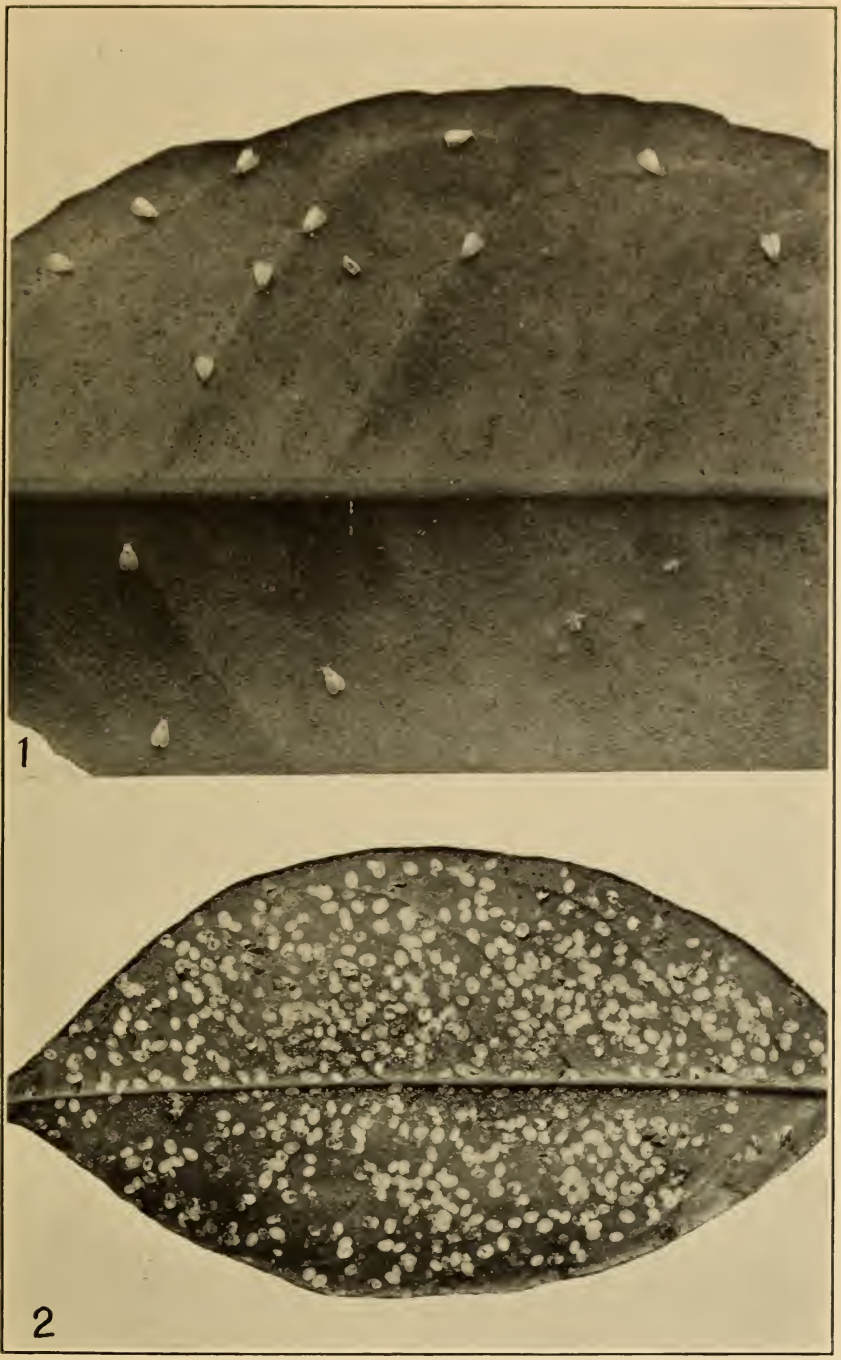
be presented illustrating the disastrous effect on the species resulting from overcrowding, the data itself would differ in no respect from that already presented under the general consideration of *A. citri*. Nevertheless, there is a great difference in the extent and practical bearing of this mortality among the immature forms of the two species.

### The Adult.

The adult of the cloudy-winged white fly is similar to that of the citrus white fly, but is at once separated from it by the dark spot or shading on the outer portion of the upper wings (Pl. X, fig. 1). Except for the further fact that the female is appreciably more robust the adults of both species are structurally much alike. The antennæ of *A. nubifera* are not as highly corrugated as those of *A. citri*, but possess a terminal spine over three times as long as that of *A. citri*. The eyes of *A. nubifera* are more nearly divided in many instances than those of *A. citri*, although this is a character subject to variation in both species.

On nearly all features of life history and habits this species closely resembles the citrus white fly, and these subjects are therefore dealt with in a comparatively brief manner. The principal points wherein the cloudy-winged white fly differs from the citrus white fly may be stated summarily as follows: It is more closely restricted to citrus for its food supply as well as in oviposition; it shows a more strongly developed tendency to feed and deposit eggs on new growth; its arrangement of eggs and preferences for certain sections of leaves for ovipositing are characteristic, and it is slightly less prolific. Its apparent restriction to citrus as a food plant has been discussed under the subject of "Food plants." Its strong preference for new growth results in a situation which can be taken advantage of in the control of the pest by the pruning of water shoots.

The age at which oviposition begins and the activity in oviposition during different parts of the day are the same as for *A. citri*. The females, however, when not abundant deposit more readily along the outer margin of the under surface of the leaf and along the edge and upper surface, and not so freely along the midrib as is the case with *A. citri*. Not infrequently 90 per cent of the eggs will be deposited on the outer portion of the leaf while many are laid on the edge of the leaf itself, from which they often project perpendicularly. The depositing of eggs on the leaf margin and on the upper surface is peculiar to *A. nubifera* and is not the result of overcrowding. A count of 4,000 eggs on nine moderately infested leaves showed that 8.1 per cent of the eggs were laid on the edge of the leaf, 86.8 per cent on the lower surface, and 5.1 per cent on the upper surface. When adults are very numerous both surfaces of the leaves of tender growth and the petioles and shoot stems are thickly covered with




THE CLOUDY-WINGED AND CITRUS WHITE FLIES.

Fig. 1.—Adults of the cloudy-winged white fly, *A. nubifera*, showing cloud or spot at tip of wings, and many eggs scattered about. Fig. 2.—Larvæ and pupæ of both the citrus white fly and the cloudy-winged white fly killed by fumigation. During life they are nearly transparent and seen only with difficulty. Note eggs of *A. citri* along midrib. (Original.)

eggs. While the citrus white fly deposits her eggs without any definite arrangement, the cloudy-winged white fly, like many other species of Aleyrodes, very frequently lays hers in arcs of various sizes, and, as she is less restless while feeding, has a tendency to deposit her eggs in groups. This arrangement, together with the difference in color, makes easy the separation of the two species.

Reference to the data in Table XXII, especially when compared with that in Table XII, shows that the daily rate of oviposition for the cloudy-winged white fly is slightly less than for the citrus white fly. As much of the data in Table XXII was obtained before typical summer weather had set in, it is of more value as demonstrating the relative rate of oviposition between the two species.

TABLE XXII.—*Daily rate of oviposition of A. nubifera and A. citri compared.*

| Record No. | Date eggs deposited. | Duration of egg laying. | Number of females of— | | Number of eggs deposited by | | Average number eggs per female per 24 hours laid by— | | Average mean temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Citri. | Nubifera. | Citri. | Nubifera. | Citri. | Nubifera. | |
| | | *Hours.* | | | | | | | °*F.* |
| 1 | Apr. 20–21, 1909 | 23 | 50 | 45 | 454 | 345 | 9.4 | 8 | 76 |
| 2 | Apr. 21–22, 1909 | 24 | 40 | 44 | 405 | 432 | 10.1 | 9.8 | 80 |
| 3 | ....do.... | 24 | ..... | 16 | ..... | 200 | ..... | 12.5 | 80 |
| 4 | Apr. 22–24, 1909 | 48 | ..... | 36 | ..... | 662 | ..... | 9.2 | 78 |
| 5 | Apr. 24–26, 1909 | 48 | ..... | 26 | ..... | 516 | ..... | 9.9 | 80 |
| 6 | June 16–17, 1909 | 24 | 30 | 79 | 360 | 849 | 12 | 10.8 | 82 |
| 7 | July 16–17, 1907 | 24 | ..... | 150 | ..... | 1,558 | ..... | 10.4 | 82 |

The number of eggs deposited by single females has not been definitely determined. However, as experiments have shown that adults of *A. nubifera* are capable of living as long as those of *A. citri* and have been known to maintain unimpaired an average of about 1 egg per day less than *A. citri* for at least seven days, it is safe to say that the maximum egg laying capacity is not far from 200.

When all food plants other than citrus are eliminated, the remarks covering the relation between oviposition and food supply for *A. citri* hold for *A. nubifera*, with the exception that oviposition with the latter species is far more dependent upon new growth. This last fact, as discussed under mortality of larvæ and pupæ due to overcrowding, has a most important bearing on the control of this species.

After a grove has been well infested with the cloudy-winged white fly there exists the same high percentage of females as recorded under the same topic for *A. citri*. In fact, the same proportions of sexes, and the same fluctuations and dependence of sex on parthenogenesis, are found to occur with *A. nubifera*. A typical example is the condition found in one grove infested entirely by this species. During the summer preceding winter fumigation the ratio between females and males was 71.4: 28.6 per cent. After fumigation, when

over 99 per cent of the cloudy-winged white fly were killed, the females of the spring brood were so very few in number and so scattered that they deposited a very large percentage of infertile eggs, resulting in a second brood in September, 62.8 per cent of which were males. In other words, after the natural equilibrium between sexes had been disturbed by fumigation, there followed as the result of parthenogenesis a decided fluctuation between a predominance of females in one and of males in the following generations. Gradually this fluctuation diminishes until normal conditions obtain.

While less attention has been given the problems connected with the emergence of this species, observations have shown that the process and time required for emergence and the changes in color occurring thereafter are the same as for the citrus white fly, with the exception of the cloud at the tip of the wing already mentioned. Statements made concerning the conditions favorable and unfavorable for the emergence of the citrus white fly hold for this species. An examination of the extensive daily emergence records on file and summarized in Table XXIII show that even during October and early November emergence did not occur below an average daily mean temperature of 62° F. The emergence occurring later in the fall, and consequently during cooler weather, does not appear to be due to more resistance to cold, but to a difference in seasonal history.

### Length of Life Cycle.

From a study of the length of the egg, larval, and pupal stages already given one can obtain an accurate knowledge of the length of the life cycle. A general summary of the data already presented in connection with these various stages is presented in Table XXIII.

Table XXIII.—*Length of life cycle of cloudy-winged white fly at Orlando, Fla.*

| Lot. | Eggs deposited. | First fly emerged. | Last fly emerged in fall. | First fly emerged in spring. | Last fly emerged. | Least number of days for development. | Largest number of days for development. | Per cent emerging before winter. | Per cent wintering over to emerge in spring. | Least number degrees effective temperature for development. | Degrees accumulating before spring emergence. | Degrees accumulating before last fly emerged. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 1.. | Apr. 20 | June 10 | ..... | ..... | ..... | 51 | 334 | ..... | ..... | 1,890 | ..... | ..... |
| No. 2.. | June 16 | Aug. 2 | ..... | ..... | ..... | 47 | ..... | ..... | ..... | 1,849 | ..... | ..... |
| No. 3.. | Aug. 23 | Oct. 14 | Oct. 31 | Mar. 20 | May 16 | 52 | 266 | 64.7 | 35.3 | 1,899 | 5,205 | 7,062 |
| No. 4.. | Sept. 4 | Oct. 23 | Nov. 1 | ...do..... | Apr. 1 | 49 | 209 | 26.8 | 73.2 | 1,693 | 4,706 | 5,055 |
| No. 5.. | Sept. 18 | Mar. 22 | 0 | Mar. 22 | May 5 | 185 | 229 | 0 | 100 | 4,650 | 4,650 | 5,915 |
| No. 6.. | Sept. 21 | Mar. 25 | 0 | Mar. 25 | May 20 | 185 | 241 | 0 | 100 | 4,638 | 4,638 | 6,318 |
| No. 7.. | Oct. 2 | Mar. 18 | 0 | Mar. 18 | ..... | 167 | ..... | 0 | 100 | 4,006 | 4,006 | ..... |
| No. 8.. | ...do..... | Mar. 20 | 0 | Mar. 20 | ..... | 169 | ..... | 0 | 100 | 4,073 | 4,073 | ..... |
| No. 9.. | Oct. 22 | Mar. 21 | 0 | Mar. 21 | Apr. 9 | 150 | 169 | 0 | 100 | 3,549 | 3,549 | 4,056 |

It will be noted that 47, the least number of days required for development, is but slightly higher than the minimum for *A. citri*, even during most favorable weather conditions. The greater average

number of days required for development, shown especially by comparisons of lots 1, 3, 6, and 7 of Table XXIII and lots 4, 5, 14, and 15 of Table XV, is not the result of chance circumstances, but actually the result of slower general development under identical conditions. This fact is perhaps more forcibly brought out by the data in Table XXIV:

TABLE XXIV.—*Rate of development of A. citri and A. nubifera compared.*

| Date. | Citri. | | | | Nubifera. | | | |
|---|---|---|---|---|---|---|---|---|
| | Instar 1. | Instar 2. | Instar 3. | Instar 4. | Instar 1. | Instar 2. | Instar 3. | Instar 4. |
| | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| July 6 | 11.7 | 88.3 | 0 | 0 | 77.9 | 22.1 | 0 | 0 |
| July 8 | 2.1 | 82.7 | 15.2 | 0 | 6.9 | 92.1 | 1.0 | 0 |
| July 12 | .7 | 10.5 | 89.8 | 0 | 1.4 | 30.8 | 67.8 | 0 |
| July 16 | 0 | 4.8 | 86.1 | 9.0 | 0 | 8.1 | 91.1 | 0.8 |
| July 21 | 0 | 2.9 | 20.6 | 76.7 | 0 | 5.9 | 62.2 | 31.9 |
| July 25 | 0 | 0 | 6.1 | 93.9 | 0 | .8 | 22.5 | 76.7 |
| July 29 | 0 | 0 | 0 | 100.0 | 0 | 0 | 14.9 | 85.1 |
| October 5 | 98.4 | 1.6 | 0 | ..... | 99.6 | .4 | 0 | 0 |
| October 11 | 8.0 | 92.0 | 0 | 0 | 35.8 | 64.2 | 0 | 0 |
| October 15 | .6 | 59.4 | 40.0 | 0 | 2.9 | 96.0 | 1.1 | 0 |
| October 23 | .6 | 4.3 | 90.7 | 0 | 2.8 | 48.8 | 48.3 | 0 |
| October 31 | 0 | 2.4 | 17.2 | 4.4 | 1.8 | 20.9 | 75.4 | 1.8 |
| November 11 | 0 | .9 | 1.9 | 80.3 | 0 | 3.3 | 90.0 | 6.6 |
| December 3 | 0 | 0 | 1.9 | 97.1 | 0 | 0 | 28.2 | 71.8 |
| December 7 | 0 | 0 | 0 | 98.1 | 0 | 0 | 12.7 | 87.3 |
| December 17 | 0 | 0 | 0 | 100.0 | 0 | 0 | 4.2 | 95.8 |
| December 26 | 0 | 0 | 0 | 100.0 | 0 | 0 | 0 | 100.0 |

In this table is shown the corresponding progress of growth of both species on various dates after egg deposition. The data concerning development during July refer to larvæ hatching from eggs laid on June 16, 1909, and that during October, November, and December to larvæ hatching from eggs deposited on September 18, 1909. For these records, leaves on the same shoot were chosen for deposition of the eggs of each species; hence both species were subject to identical climatic and nutritive conditions.

A study of the data in Tables X and XXI will also prove that the same statements made for *A. citri* concerning the equalizing effect of winter on the length of the pupal stage for wintering-over pupæ are equally true for *A. nubifera*. The data show at a glance that eggs deposited in late October are capable of producing adults the following spring as early or even earlier than eggs deposited a month or, as sometimes occurs, five months earlier.

## SEASONAL HISTORY.

### GENERATIONS OF THE CLOUDY-WINGED WHITE FLY.

Aside from the fact that the adults of this species have never been seen by the authors on wing during January and early February, as have those of *A. citri*, there being therefore no winter generation

corresponding to that of *A. citri*, the statements made regarding the number of annual generations of *A. citri* is true of *A. nubifera* when the additional statement is made that the height of the various emergence periods occurs usually about two or four weeks later than the corresponding periods for *A. citri*. The emergence of adults brings about the same complications in broods and generations described for *A. citri*, resulting from variation in length of life cycle, and the double-brooded character of each generation is also to be found in the life history of *A. nubifera*. Of eggs laid August 23, 1907, 1.5 per cent produced adults between October 1 and 15 and 63.2 per cent between October 16 and 31; of the remaining pupæ wintering over, 34.6 per cent emerged between March 16 and 30 and 0.7 per cent between April 1 and 15. From eggs laid September 4, 1907, 24 per cent of the adults emerged between October 16 and 31, 2.8 per cent between November 1 and 15, 71.8 per cent between March 16 and 30, and 1.4 per cent between April 1 and 15. From eggs laid September 18, 1908, 81.6 per cent of the adults emerged between March 16 and 30, 4.1 per cent between April 1 and 15, 10.2 per cent between April 16 and 30, and 4.1 per cent between May 1 and 15. From eggs deposited March 29, 1909, 44.5 per cent emerged between June 1 and 15, no further records being kept.

It might be inferred from the slower development of *A. nubifera* that it would pass through a less number of annual generations than *A. citri*. This, however, is not true, inasmuch as its slower development is offset by its seasonal history—it remaining active later in fall and early winter.

### Seasonal Fluctuations in the Number of Adults or So-called "Broods."

Because the generations of the cloudy-winged white fly are of the same general double-brooded character as those of the citrus white fly, and are subject to the same unexplainable variation in the length of the life cycle, the seasonal history of *A. nubifera* is not unlike that of *A. citri* in nearly all essential features. In fact, the same three periods of general emergence of adults occur as with *A. citri*, but with the difference that the adults of each so-called "brood" reach their numerical maximum usually from two to four weeks later than the corresponding broods of *A. citri*. In figure 19 are given curves representing the abundance of adults of *A. citri* and *A. nubifera* at Orlando during 1909. As a result of this striking difference in the seasonal history of these two species, previous observations on this subject are considerably confused and should be disregarded unless one is positive of the species under consideration at the time. As with *A. citri*, no one definite statement can be made to cover the exact time when the emergence of various broods will begin. Emergence is strongly influenced by local weather conditions. While the curve in figure 19 represents the condition in one Orlando grove

in 1909, it is not meant to represent the abundance of adults in any other grove in that city, much less in groves in various parts of the State. The same variation in neighboring groves in the same county and in a lesser degree in different trees in the same grove occurs with *A. nubifera*, and this statement apparently holds for infested groves in any part of the State. For example, groves at Dunedin and Sutherland, in 1909, showed a difference of at least 10 days in the beginning of the active spring emergence of adults.

The most striking difference in the seasonal history between *A. citri* and *A. nubifera* which perhaps attracts most general attention and leads to more confusion between the two species in the minds of many is the much later appearance of adults of *A. nubifera* in the fall of the year. The last large "hatching" of *A. citri* is on a rapid decline at Orlando by the middle of September at the latest, while that of *A. nubifera* at that time is only approaching its maximum and lasts well toward the 1st of November, when its decline is rapid, although adults can be found during moderately warm falls as late as the middle of December. Thus at Orlando in October 18, 1907, when adult

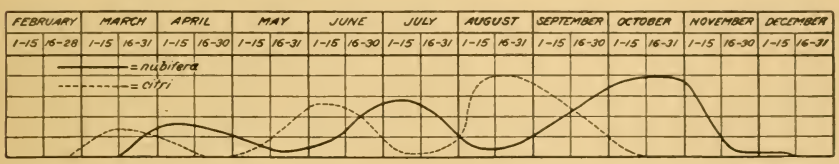



FIG. 19.—Diagram showing relative abundance of the adults of *Aleyrodes nubifera* and *A. citri*, throughout the year 1909, at Orlando, Fla. (Original.)

*A. citri* were practically off the wing and a large portion of the immature stages of *A. citri* had already reached the pupal stage, note was made that adults of *A. nubifera* were appearing in numbers and that pupæ of *A. nubifera* were rapidly developing eyespots on certain growths, and that new growth in places was crowded with ovipositing adults.

In consequence of the difference between the time of appearance of these fall broods, the immature stages of *A. citri* have largely reached the pupal stage and are prepared to winter over by the last of October. At this time females of *A. nubifera* are crowding the limited new growth with large numbers of eggs, and by far the larger proportion of this species will be found in the egg and larval stages up to the middle of December, and in a few instances third-instar larvæ may be found as late as the middle of February. It will be seen, therefore, from this and the foregoing data that there is no time during the season, except for about two months before spring emergence first sets in, that all stages can not be found in the grove in varying degrees of abundance.

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